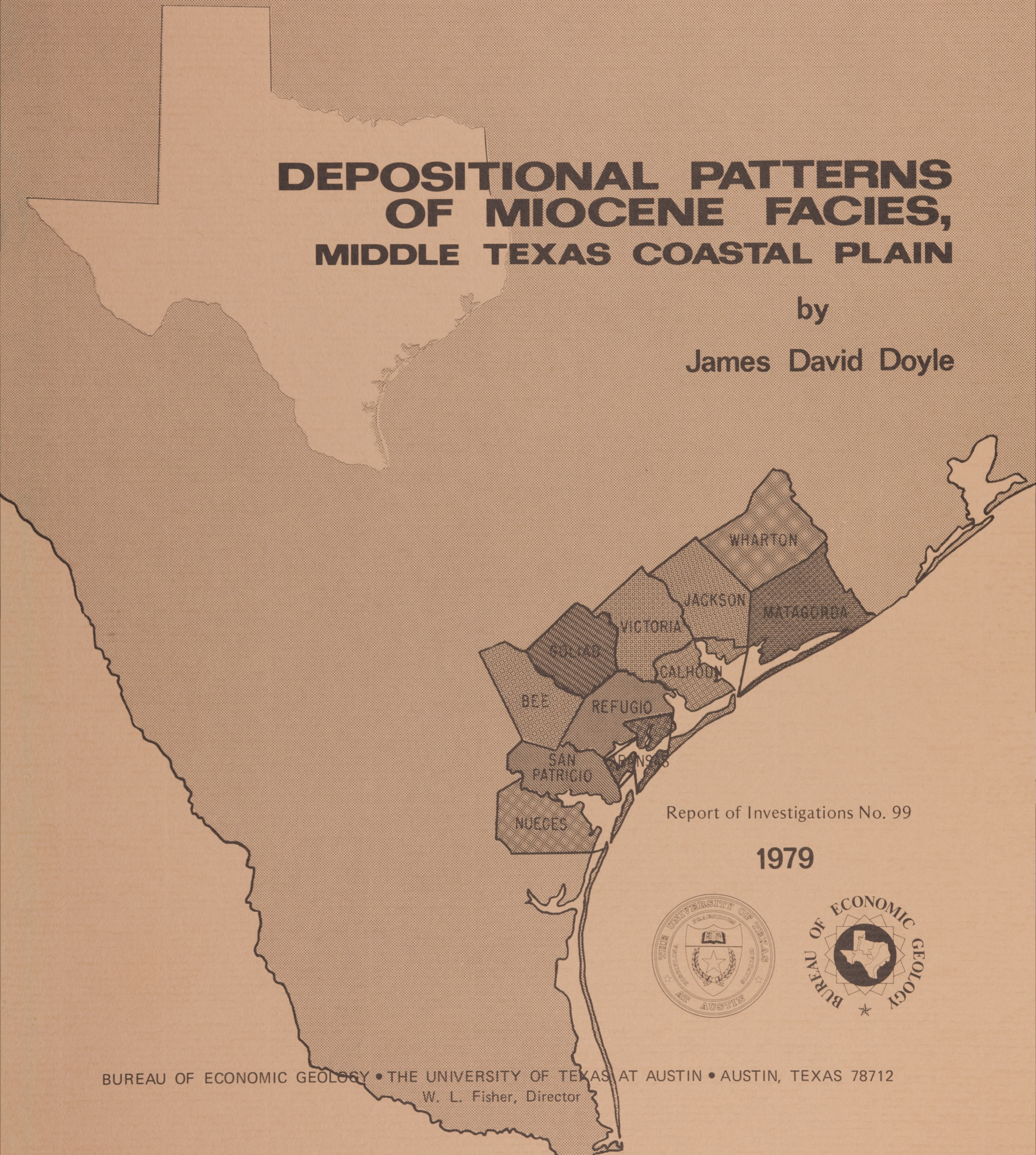
DEPOSITIONAL PATTERNS OF MIOCENE FACIES, MIDDLE TEXAS COASTAL PLAIN

by

James David Doyle



Report of Investigations No. 99

1979

BUREAU OF ECONOMIC GEOLOGY • THE UNIVERSITY OF TEXAS AT AUSTIN • AUSTIN, TEXAS 78712

W. L. Fisher, Director

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DEPOSITIONAL PATTERNS OF MIOCENE FACIES, MIDDLE TEXAS COASTAL PLAIN

by James David Doyle[1]

ABSTRACT

Miocene strata along the Middle Texas Coast form an offlapping sequence of fluvial and deltaic sandstones and shales overlying shelf shales of the Oligocene(?) Anahuac Formation. Subdivision of Miocene strata into thin time-contemporaneous units reveals that the axis of Miocene sand deposition migrated gulfward with time until it reached a position 2 to 12 miles (7.5 km) seaward of the present coast. There, strike-fed Miocene sands were deposited in a vertical stack gulfward of the axis of maximum Oligocene Frio sand deposition. A minor transgression occurred in late Miocene followed by further gulfward progradation of Miocene depositional systems.

Mapping of Miocene sandstone distribution, along with examination of electrical-log characteristics, reveals the existence of three depositional systems within each time-contemporaneous unit: (1) an updip fluvial system with dip-oriented sands, (2) a high-destructive deltaic-strandplain system with dominantly strike-oriented sands, and (3) a downdip, distal deltaic-shelf system composed of thin sands separating prodelta and shelf muds.

Structural features greatly influenced Miocene deposition. Vertical stacking of fluvial channel-fill facies suggests a deep-seated structural control of channel positions. During much of the Miocene, large growth faults and basinal subsidence stabilized delta locations by accommodating all incoming sediment, thereby preventing progradation.

INTRODUCTION

Miocene strata form one of the many thick offlapping wedges of terrigenous sediment that were deposited in the Gulf Coast basin during the Tertiary. Along the Middle Texas Coast, Miocene strata were deposited as a regressive sequence of interbedded fluvial-deltaic sands and muds after regional transgression of the Oligocene(?) Anahuac Formation. In this area, the Miocene wedge thickens from less than 2,000 feet updip to a maximum of 10,000 feet offshore, 45 miles from the present coast (Rainwater, 1964).

Objective

By determining the distribution of Miocene sandstones and by inferring their paleoenvironments, this study is designed to aid in evaluating the potential of Miocene sandstones as disposal reservoirs for geothermal fluids that may be produced from the Frio Formation. The investigation is part of a larger study of geothermal resources being conducted by the Bureau of Economic Geology, The University of Texas at Austin (Bebout and others, 1975a, 1975b, 1976, 1978).

Location

This investigation involved Miocene strata in the subsurface of an area of approximately 7,900 square miles (fig. 1). The area extends from central Nueces County on the southwest to the San Bernard River on the northeast and up to 15 miles offshore in the Gulf of Mexico. It includes all or part of Aransas, Bee, Brazoria, Calhoun, Goliad, Jackson, Matagorda, Nueces, San Patricio, Victoria, and Wharton Counties. The study area is approximately the same as that of the Middle Texas Gulf Coast Frio study by Bebout and others (1975b).

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[1] Cities Service Oil Company, Houston, Texas.

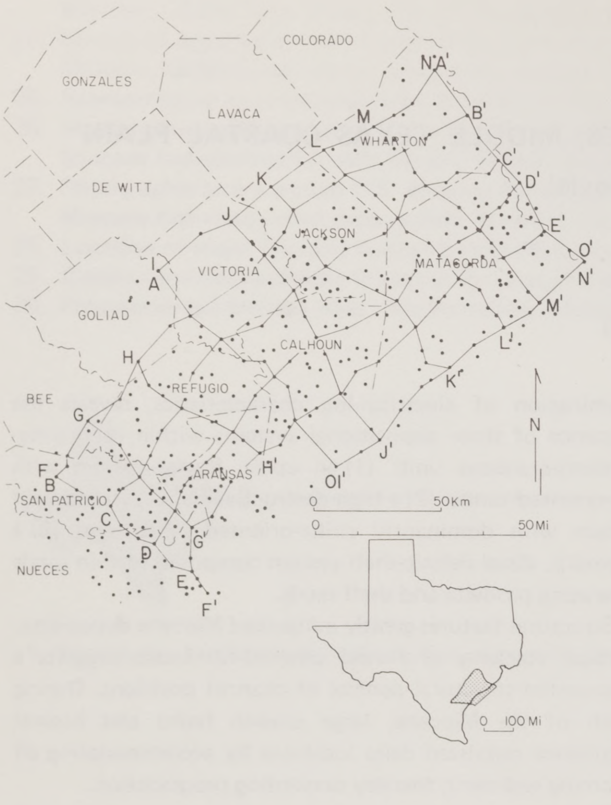


Figure 1. Location of study area, Middle Texas Coast, showing location of wells and cross sections. Wells are numbered by county and listed in the appendix.

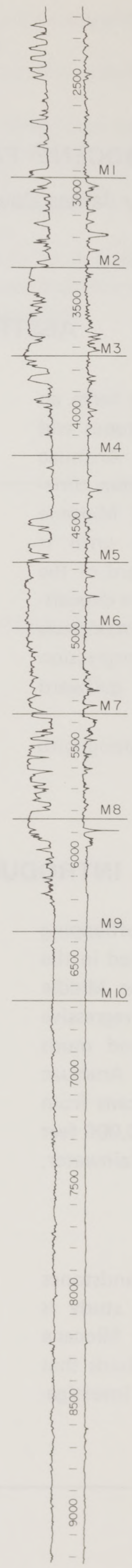
Interval Studied

The stratigraphic interval studied (figs. 2 and 3) is bounded below by shelf clays of the Anahuac Formation and above by Pliocene(?) fluvial facies. Ten correlation horizons, M_1 to M_{10}, are used to subdivide the interval into nine units, M_1-M_2 being the youngest and M_9-M_{10} the oldest. The lower boundary is easily traced on electrical logs throughout the map area, whereas the upper boundary and internal subdivisions are more difficult to correlate.

The interval studied is a clastic wedge that thickens toward the coast. As shown in figure 4, the interval ranges from less than 2,000 feet thick in Wharton County to greater than 7,000 feet thick offshore from Matagorda County. Correlation of the base of the interval (correlation horizon M_{10}) with offshore Texas subsurface stratigraphy is difficult to establish. Contour values offshore in the Gulf of Mexico therefore represent only the thicknesses of the upper eight subdivisions of the interval (M_1-M_9).

Terminology

Terminology employed in this report is that used by Fisher and others (1969) in their description of depositional systems, which they define as "assemblages of process-related



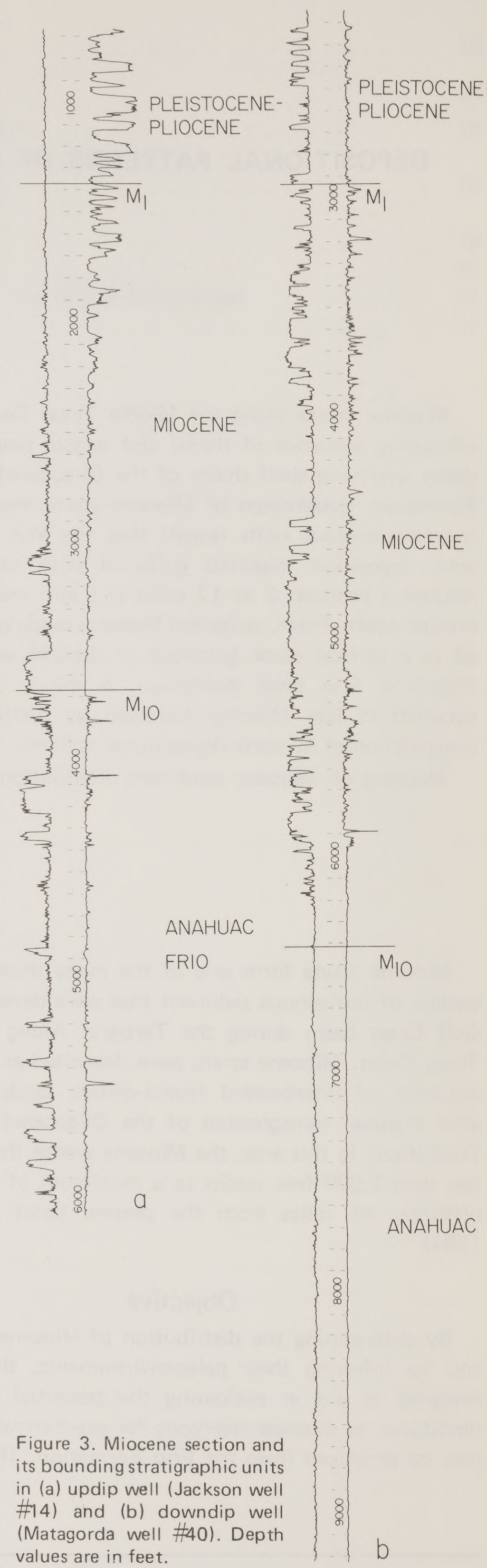


Figure 3. Miocene section and its bounding stratigraphic units in (a) updip well (Jackson well #14) and (b) downdip well (Matagorda well #40). Depth values are in feet.

Figure 2. Correlation horizons M_1-M_{10}, used to subdivide the Miocene section (Matagorda well #40). Depth values are in feet.

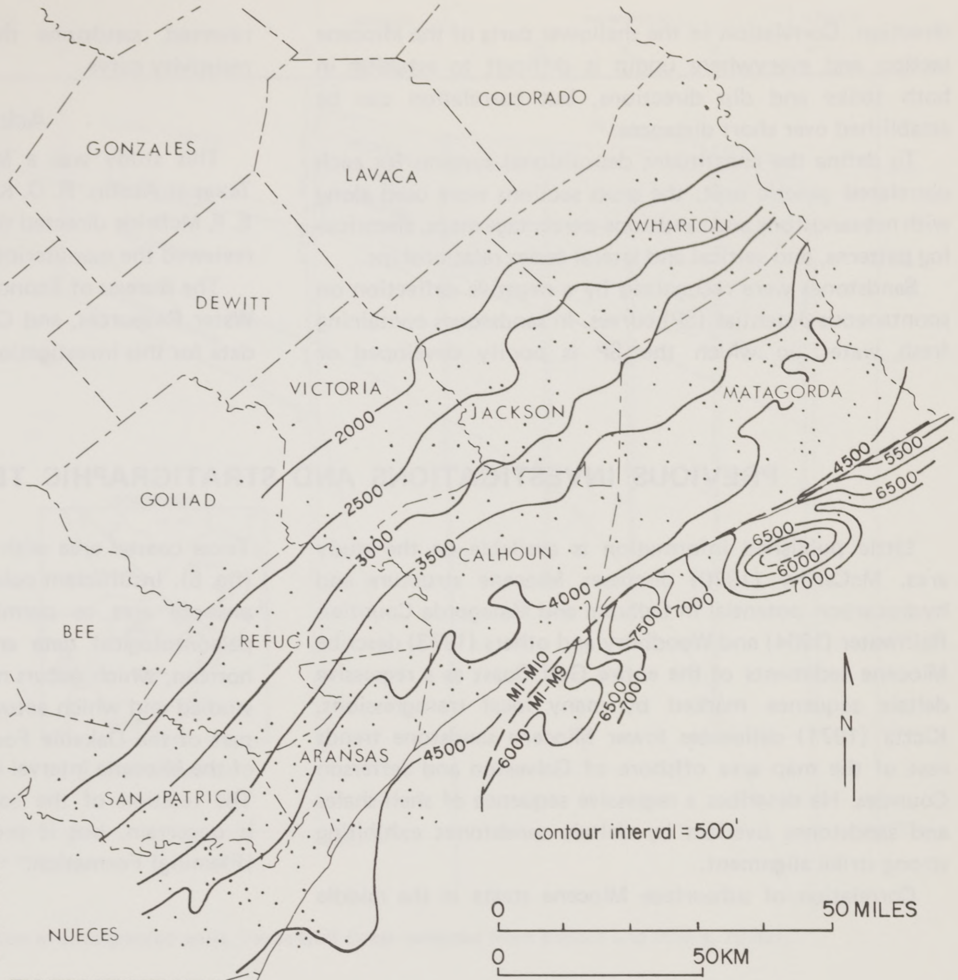


Figure 4. Isopach map, Miocene strata, Middle Texas Coast. Onshore contours show total thickness of Miocene section. Offshore contours indicate thickness of upper eight Miocene units (M_1-M_9). Insufficient penetration of the base of the Miocene (M_{10}) precludes mapping total unit thickness offshore.

sedimentary facies." Depositional systems can be interpreted for a time-stratigraphic unit from sand distribution patterns, electrical-log patterns, and vertical and lateral facies relationships within the unit. Interpretation of sediment textures from electrical-log patterns is discussed by Fisher and others (1969).

Methods of Study

Each subdivision (nine units) of the Miocene has been interpreted as comprising facies assemblages representing three depositional systems: fluvial, deltaic-strandplain, and distal deltaic-shelf. Determination of the depositional framework required correlation of 442 wells uniformly distributed over the map area (fig. 1). Wells used in the investigation are listed in the appendix. In order to establish a three-dimensional framework of well-log data and to aid in making correlations, a regional grid of nine stratigraphic dip sections and six stratigraphic strike sections was constructed. The positions of the dip and strike sections are shown in figure 1. Stratigraphic cross sections also aid in understanding the regional geometry of sandstone and shale bodies, which in turn facilitates determination of facies depositional patterns.

Regional correlation within the Miocene is based principally on electrical-log character because paleontological information is available only locally and is restricted to the lower part of the Miocene section. In particular, the marker horizons M_9 and M_{10} generally coincide with *Siphonina davisi* and *Discorbis gravelli,* respectively; horizons M_1 to M_8 are based entirely on electrical-log characteristics. Electrical-log correlations were made using resistivity character within shale sections. Shale sections are inferred as constituting approximate time-stratigraphic markers; consequently, the interval between two correlation markers is a "Genetic Increment of Strata" (GIS) as described by Busch (1971). Sediments in a GIS were deposited during a brief time interval and are thus representative of the depositional systems operative during that time interval. Mapping sandstone distribution within a GIS should reflect facies distribution during deposition of the GIS. Where a shale marker grades into sandstone, correlation is approximated by tracing local markers above and below the sandstone.

Correlation in the lower parts of the Miocene section and throughout the downdip Miocene section is easy to establish along strike direction and more difficult in the dip direction. Correlation in the shallower parts of the Miocene section and everywhere updip is difficult to establish in both strike and dip directions, but correlation can be established over short distances.

To define the constituent depositional systems for each correlated genetic unit, the cross sections were used along with net-sandstone and sandstone-percentage maps, electrical-log patterns, and vertical and lateral facies relationships.

Sandstones were recognized by a negative deflection on spontaneous-potential (SP) curves. In sandstones containing fresh water, in which the SP is poorly developed or reversed, sandstone thickness was calculated from the resistivity curve.

Acknowledgments

This study was a Master's thesis at The University of Texas at Austin. R. O. Kehle (supervisor), D. G. Bebout, and E. F. McBride directed the research project. L. F. Brown, Jr., reviewed the manuscript.

The Bureau of Economic Geology, Texas Department of Water Resources, and Cities Service Oil Company provided data for this investigation.

PREVIOUS INVESTIGATIONS AND STRATIGRAPHIC TERMINOLOGY

Little published information is available on the study area. McCarthy (1970) discusses Miocene structure and hydrocarbon potential in Calhoun and Matagorda Counties. Rainwater (1964) and Woodbury and others (1973) describe Miocene sediments of the entire Gulf Coast as a regressive deltaic sequence marked by many local transgressions. Kiatta (1971) delineates lower Miocene sandstone trends east of the map area offshore of Galveston and Jefferson Counties. He describes a regressive sequence of shelf shales and sandstones overlain by deltaic sandstones exhibiting strong strike alignment.

Correlation of subsurface Miocene strata in the middle Texas coastal area with the outcrop is difficult to establish (fig. 5). Insufficient paleontological data are available in the onshore area to permit this correlation. None of these paleontological data are shallower than *Siphonina davisi* horizon, which occurs near the base of the Miocene interval studied and which actually may be equivalent to the lower part of the Oakville Formation (Rainwater, 1964). The top of the Miocene interval is based on electrical-log correlation. The relation of the top of the interval to outcrop units is uncertain, but it probably correlates with the Lagarto (Fleming) Formation.

STRUCTURE

The generalized structural configuration of Miocene strata is illustrated by a map contoured on the M_7 marker horizon, the lowest marker on most electrical logs (fig. 6). Miocene strata generally dip toward the coast at 75 feet per mile with dip increasing to 700 feet per mile along the present coastline in southern Calhoun and Matagorda Counties. The high dip identifies a major Miocene growth fault with throw greater than 2,000 feet. Uniform coastward dip is interrupted in the immediate vicinity of four salt domes in the eastern onshore part of the study area (fig. 6).

A major positive linear structural ridge extends from southeastern Calhoun County to south-central Matagorda County (fig. 6). The ridge is depicted on the structure map (fig. 4); its presence is substantiated on the isopach map by the isopach thinning. More detailed mapping by McCarthy (1970) shows the structural feature to be two anticlinal ridges—the Steamboat Pass - Collegeport Ridge and the Miocene Uplift. Both ridges are located south of a Miocene fault complex.

Offshore, Miocene strata are complexly faulted, but with limited well control and absence of seismic data, detailed structural mapping is very difficult. Onshore, Miocene strata are structurally less complex than the older Frio Formation, which is complexly faulted. Even so, growth faults with throws of several hundred feet cut the Miocene section. In the southwestern part of the area, the effect of these growth faults is not evident on dip sections F-F' to H-H' (figs. 7 and 8), but to the northeast, expansion of the section across the large Miocene growth fault is evident on sections I-I' to N-N' (figs. 9 and 10). Lower Miocene genetic units expand across the faults by a ratio of up to 2 to 1. The fault dies out upward and has little, if any, effect on units M_1-M_2 and M_2-M_3.

In places, large Frio growth faults exert an influence on the shallower Miocene section. Generally, however, the large Oligocene faults that cut the Frio were inactive during Miocene time. Cross section H-H' (fig. 8) illustrates a Frio fault that affected Miocene sedimentation. Well A_5 is on the downthrown block of a large Frio fault; A_7 is located on a Frio rollover structure; and A_{10} is on the downthrown block of another Frio fault. Thickening of the Miocene section by 180 and 300 feet in wells A_5 and A_{10}, respectively, relative to well A_7, demonstrates that movement along the faults continued into the Miocene. Cross section N-N' (fig. 10) displays a similar relationship between wells M_1 and B_3.

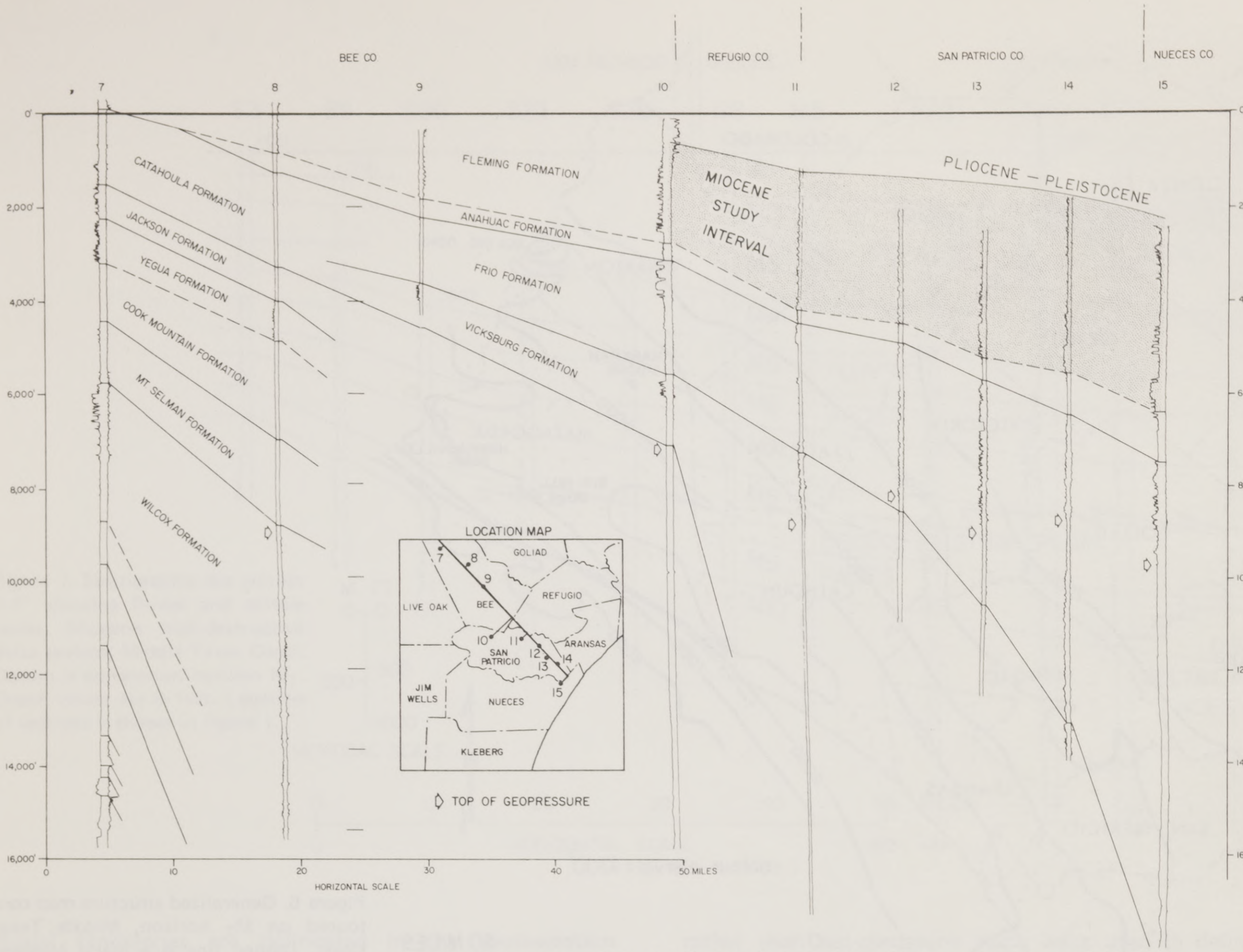


Figure 5. Dip section showing distribution of stratigraphic units, Texas Gulf Coast (adapted from Bebout and others, 1976b).

As described by Bruce (1973), growth faulting may occur as a result of differential compaction where sand is deposited on a thick sequence of undercompacted and overpressured shale. Such contemporaneous faults permit considerable expansion of the section on the downthrown side. Where the rate of subsidence along the fault balances the input of sediment into the basin, depositional environments may be stabilized (Bruce, 1973). On the other hand, growth faults may form wherever the depositional environments are stabilized (R. O. Kehle, 1976, personal communication). Where environments have been stabilized, continued movement along a curved fault plane causes rotational movement of the downthrown block, resulting in a marked counter-regional dip.

DEPOSITIONAL SYSTEMS

General Statement

According to Fisher and others (1969), delta morphology reflects the relation of the rate of sediment supply to the wave and current energy of the receiving basin. Where sediment input is high relative to basin energy, fluvial facies dominate, and high-constructive deltas are produced. With low sediment input and high basin energy, marine processes dominate, and high-destructive deltas result. Other modifying factors include climate, basin subsidence, and the sand/mud ratio of transported sediment.

Fisher and others (1969) characterize high-destructive, wave-dominated deltas as having

1. Chevron or cuspate shapes exhibiting both strike- and dip-oriented sand trends.
2. Abundant destructional facies and subordinate constructional facies.
3. Moderate volumes of sediment displaying a high sand/mud ratio.
4. Local source areas.
5. Thin prodelta facies.
6. Strandplain facies as a component of the delta system.

Figure 11 is an idealized net-sand pattern for a high-destructive, wave-dominated delta.

Sandstone Distribution and Interpretation

From Nueces to Victoria Counties, the sandstones of genetic unit M_9-M_{10} (fig. 12) are dominantly strike aligned and reach cumulative thicknesses greater than 300 feet. The

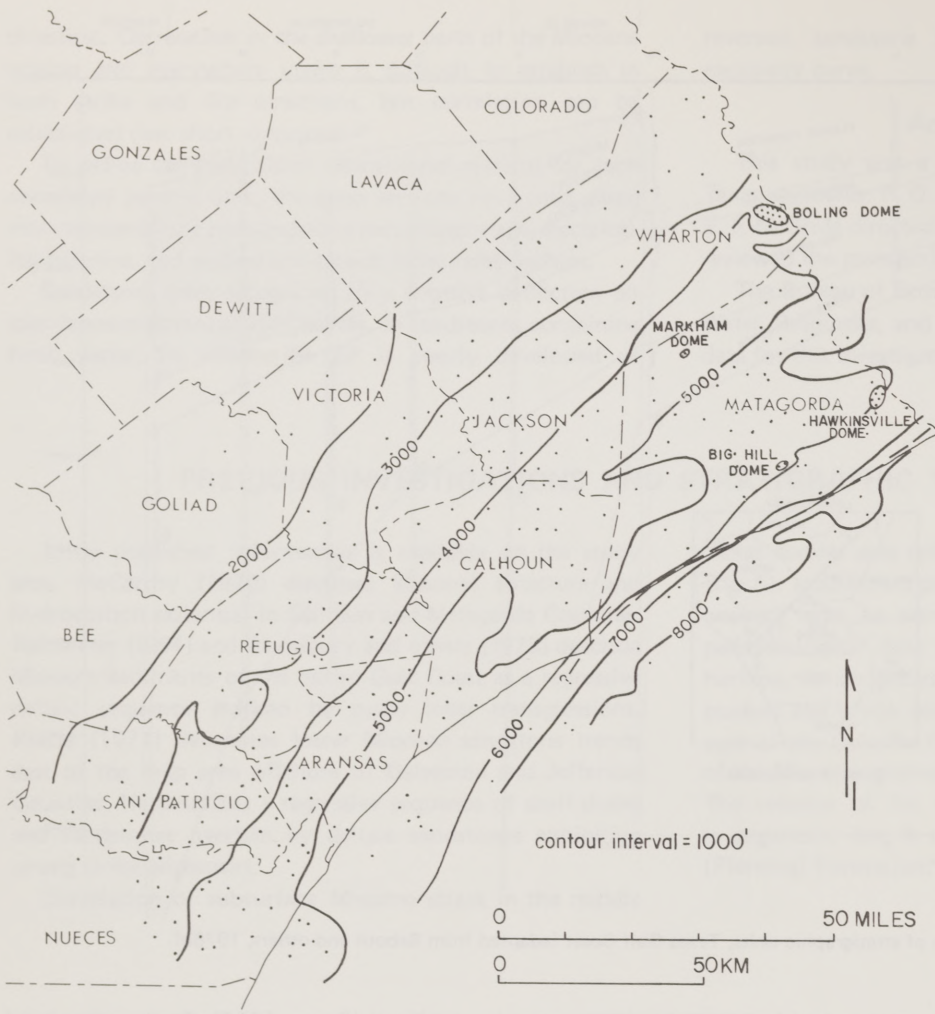


Figure 6. Generalized structure map contoured on M_7 horizon, Middle Texas Coast. Dashed line is a major Miocene growth fault complex. Salt domes are also shown.

sandstones also exhibit a subordinate dip orientation. The sandstone pattern is interpreted as representing a high-destructive, wave-dominated delta system. In San Patricio and Refugio Counties, some fluvial feeder systems are recognized in unit M_9-M_{10}. Less sand and no feeder systems are found in Jackson and Wharton Counties; this area is interpreted as representing strandplain facies.

Orientation of the sandstone trends in genetic unit M_8-M_9 (fig. 13) indicates a high-destructive delta system. In eastern Nueces County, for example, more than 400 feet of sandstone is located along the strike-fed trend. Unit M_8-M_9 contains better developed fluvial feeder sandstones than does unit M_9-M_{10}. Also, the axis of maximum sandstone deposition in unit M_8-M_9 is displaced 25 to 40 miles gulfward relative to the underlying genetic unit. The greatest gulfward displacement is in the eastern part of the map area where deltaic sedimentation dominated during deposition of unit M_8-M_9, but not during deposition of unit M_9-M_{10}. In southwestern Matagorda County, deltaic sediments accumulated on the downthrown side of a major Miocene growth fault.

Except in eastern Matagorda County, the axis of maximum sandstone deposition for unit M_7-M_8 (fig. 14) prograded 1.5 to 9 miles offshore from the present coastline. Strike-aligned sands accumulated on the downthrown side of the large Miocene growth fault. Net-sandstone thickness values along the axis of deposition range from 500 to greater than 1,050 feet. In the southwest part of the map area, only dip-oriented fluvial feeder systems were recognized. Projection of the strike-oriented sandstone trend to the southwest places the thick sequence of strike-fed sandstones gulfward of available well control.

Sandstone distribution patterns for genetic units M_7-M_8 to M_3-M_4 (figs. 14 through 18) vary little except for shifting of the positions of maximum deltaic sedimentation. In each genetic unit, areas exhibiting the greatest thickness of sandstone are aligned in narrow, strike-oriented bands. These bands trend from southern Matagorda County to a position seaward from Calhoun County. From the time of deposition of unit M_6-M_7 to that of unit M_4-M_5, the axis of maximum sandstone deposition in southeastern Matagorda County prograded 10 to 13 miles gulfward.

Each genetic unit from M_7-M_8 to M_3-M_4 is interpreted as composed of a system of coalescing high-destructive deltas and associated strandplains that occur downdip from the equivalent fluvial system. For each unit, only dip-oriented

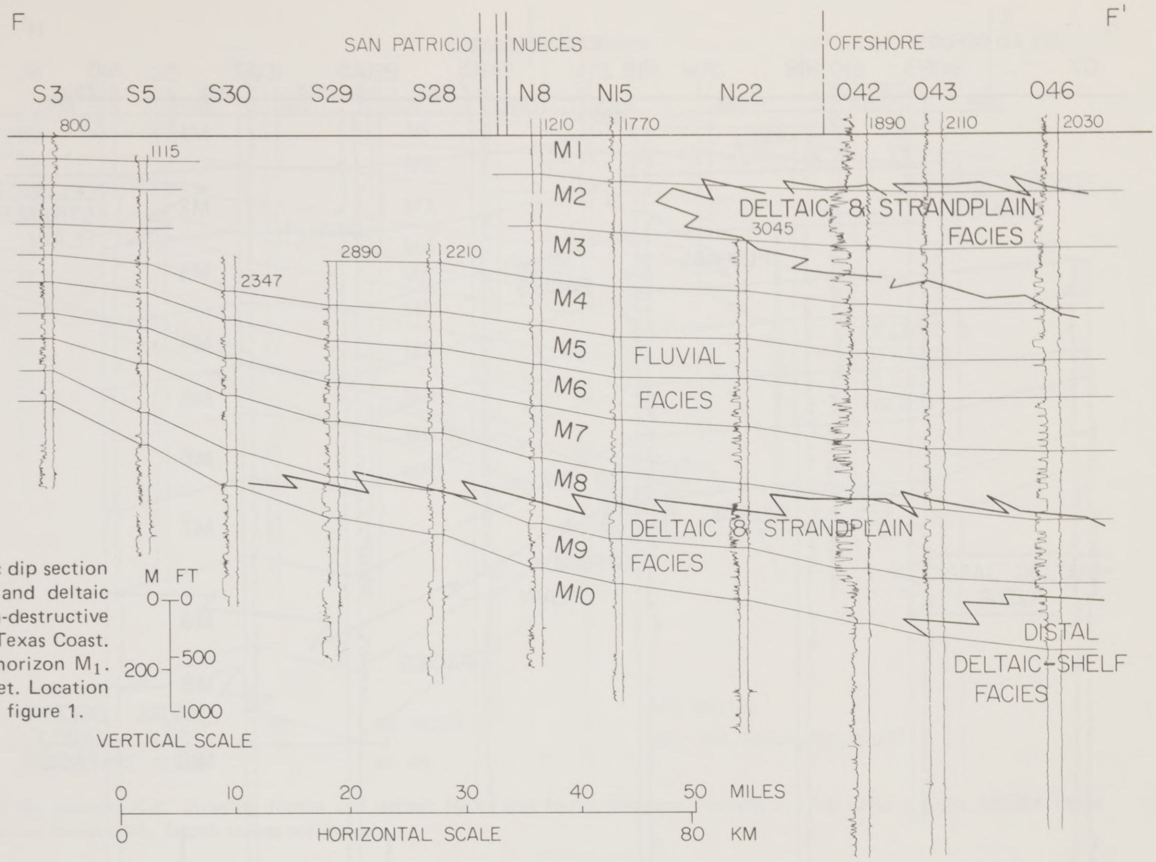


Figure 7. Stratigraphic dip section F-F' showing fluvial and deltaic facies, Miocene high-destructive delta system, Middle Texas Coast. Datum is correlation horizon M_1. Depth values are in feet. Location of sections is shown in figure 1.

fluvial sandstones are delineated in the southwestern part of the map area. Genetic unit M_2-M_3 (fig. 19) records a minor regional transgression. The axis of maximum sand deposition shifted landward approximately 12 miles. This depoaxis extends from southern Matagorda County to the present coast of Aransas and Nueces Counties. In southern Calhoun County, cumulative sandstone thicknesses reach values of 400 feet.

During deposition of genetic unit M_1-M_2 (fig. 20), Miocene depositional systems again prograded gulfward. Only dip-oriented, fluvial sandstones are present in the map area. Wells offshore from Calhoun and Matagorda Counties indicate that the fluvial system extended at least 30 miles seaward of the fluvial system within transgressive unit M_2-M_3 and 26 miles seaward of the fluvial system within unit M_3-M_4. A thick, massive, strike-fed sandstone belt is inferred as having been deposited gulfward of the study area. Cumulative sandstone thicknesses of fluvial sandstones range from 50 to 250 feet.

Net-sandstone and sandstone-percentage maps for the entire Miocene section, M_1-M_{10}, are shown in figure 21. The greatest sandstone thicknesses are offshore from the present coast. Onshore, the offlap sequence of superposed facies masks distinctive sandstone trends.

Miocene Depositional Systems

Within each Miocene genetic unit, three depositional systems are recognized: fluvial, deltaic-strandplain, and distal deltaic–shelf (fig. 22). Sandstone-percentage maps rather than net-sandstone maps were used in delineating depositional systems because sandstone-percentage maps are less affected by significant expansion of section across growth faults. Depositional systems for the nine genetic units are illustrated in figures 22, 23, and 24.

In the downdip regions, the distal deltaic-shelf system has arbitrarily been defined as sequences containing less than 20 percent sandstone. The distal deltaic-shelf systems include distal delta-front, prodelta, and shelf facies.

The deltaic-strandplain system includes progradational deposits composed of channel-fill and channel-mouth bar facies. The system also includes destructional units composed of coastal barrier and strandplain beach and shoreface facies. Other associated facies include lagoon and marsh deposits, but destructional facies predominate in the high-destructive deltas.

Updip with each genetic unit, the 20-percent sandstone contour was chosen as the boundary between fluvial and deltaic-strandplain systems where that contour is parallel to depositional strike. The fluvial system includes both channel-fill deposits and overbank deposits in interchannel or floodbasin areas. Sediment dispersal patterns and representative sandstone-percentage contours indicate the locations of the main dip-oriented fluvial channels that fed the deltas. The representative contour is either 20- or 40-percent sandstone, depending on the genetic unit.

Electrical logs exhibit characteristic patterns of each depositional system (fig. 25). The fluvial system consists predominantly of shale with thin sandstones 5 to 30 feet

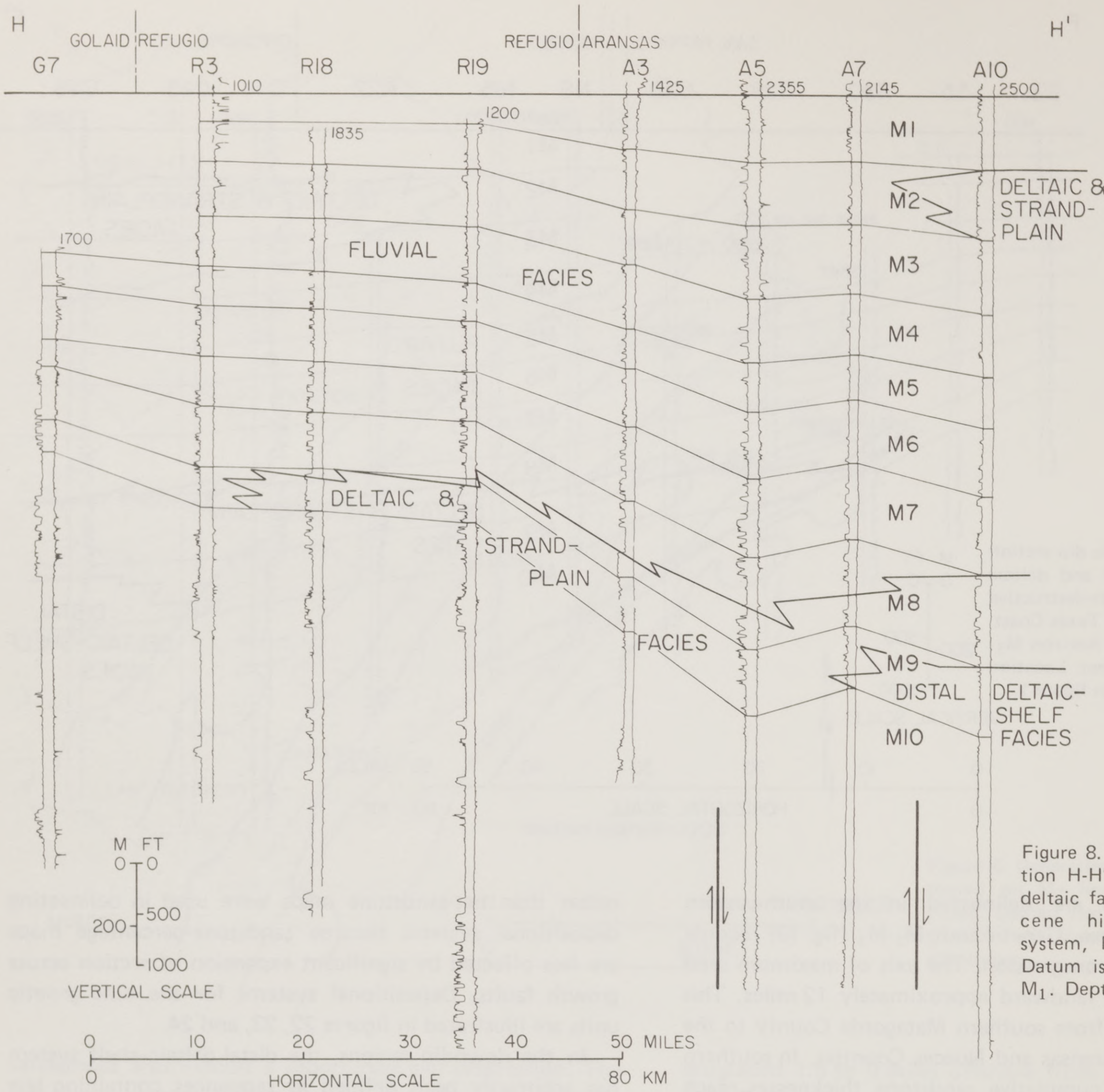


Figure 8. Stratigraphic dip section H-H' showing fluvial and deltaic facies and faults, Miocene high-destructive delta system, Middle Texas Coast. Datum is correlation horizon M_1. Depth values are in feet.

thick. These sands typically have uniform or upward-fining textures. In the deltaic system, sandstones are up to several hundred feet thick and display uniform or upward-coarsening textures. The distal deltaic-shelf system contains shales 50 to 500 feet thick and thin sandstones 5 to 50 feet thick.

Regional stratigraphic dip sections, on which inferred depositional systems have been identified, illustrate the manner in which deltaic-strandplain and fluvial systems migrated seaward with time (figs. 7 through 10). Each genetic unit grades downdip from a thin fluvial sequence composed of shale and thin sandstones to a thick deltaic section composed of shales and massive sandstones. Finally, as illustrated on the dip sections in the central and northeastern part of the map area (figs. 9 and 10), the genetic units grade downdip into thick distal deltaic-shelf deposits composed of thick shales interbedded with thin sandstones.

Regional strike sections (figs. 26 and 27) illustrate the variations in sandstone thickness along depositional strike.

STRUCTURAL CONTROL OF DEPOSITION

Main fluvial channels that were active during deposition of genetic units M_1-M_{10} were identified by high, dip-oriented sandstone-percentage trends (fig. 28). In the northeastern part of the map area, superposed channels define distinct trends. To the southwest, superposition of channels is less distinct, and channel-fill deposits occur over the entire area. Careful examination does reveal, however, that some areas have higher densities of channels than others. In most areas Miocene channels are coincident with the position of modern streams. This coincidence is unexpected because

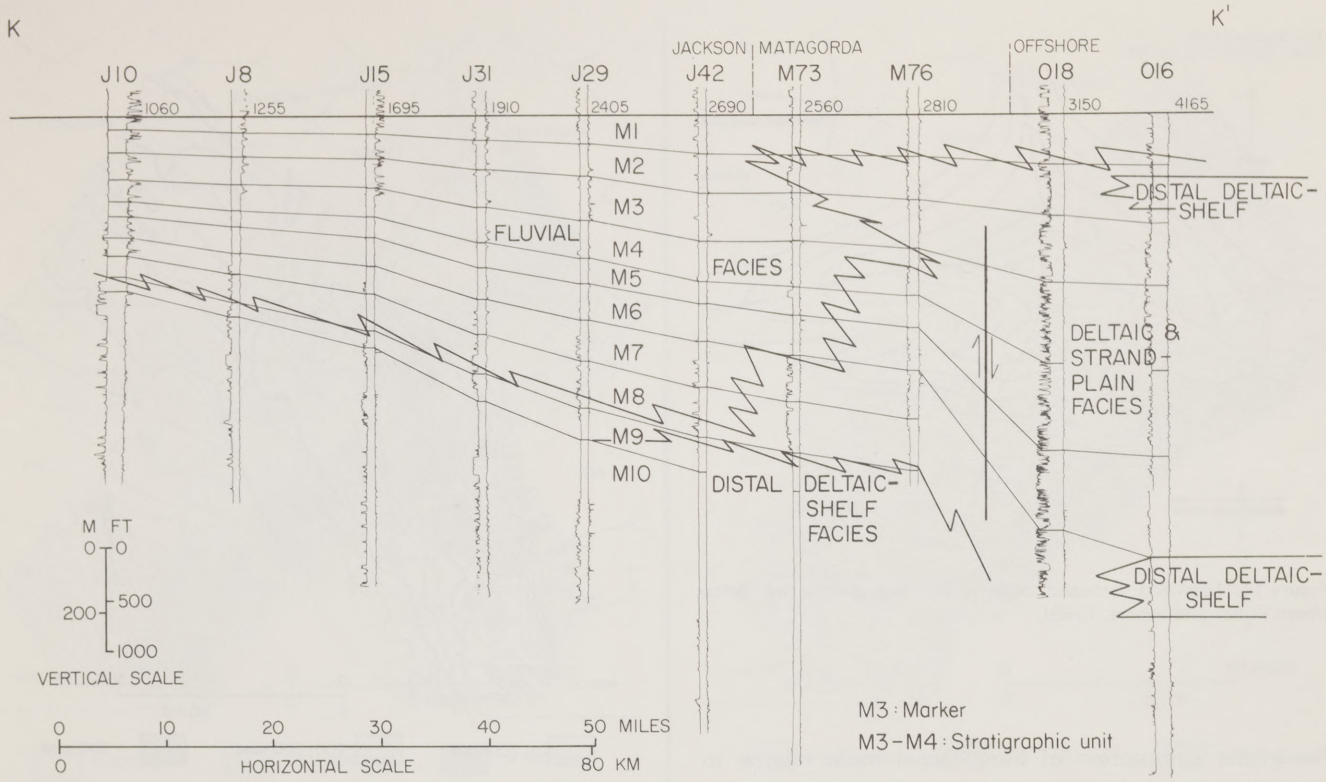


Figure 9. Stratigraphic dip section K-K' showing fluvial and deltaic facies and faults, Miocene high-destructive delta system, Middle Texas Coast. Datum is correlation horizon M_1. Depth values are in feet.

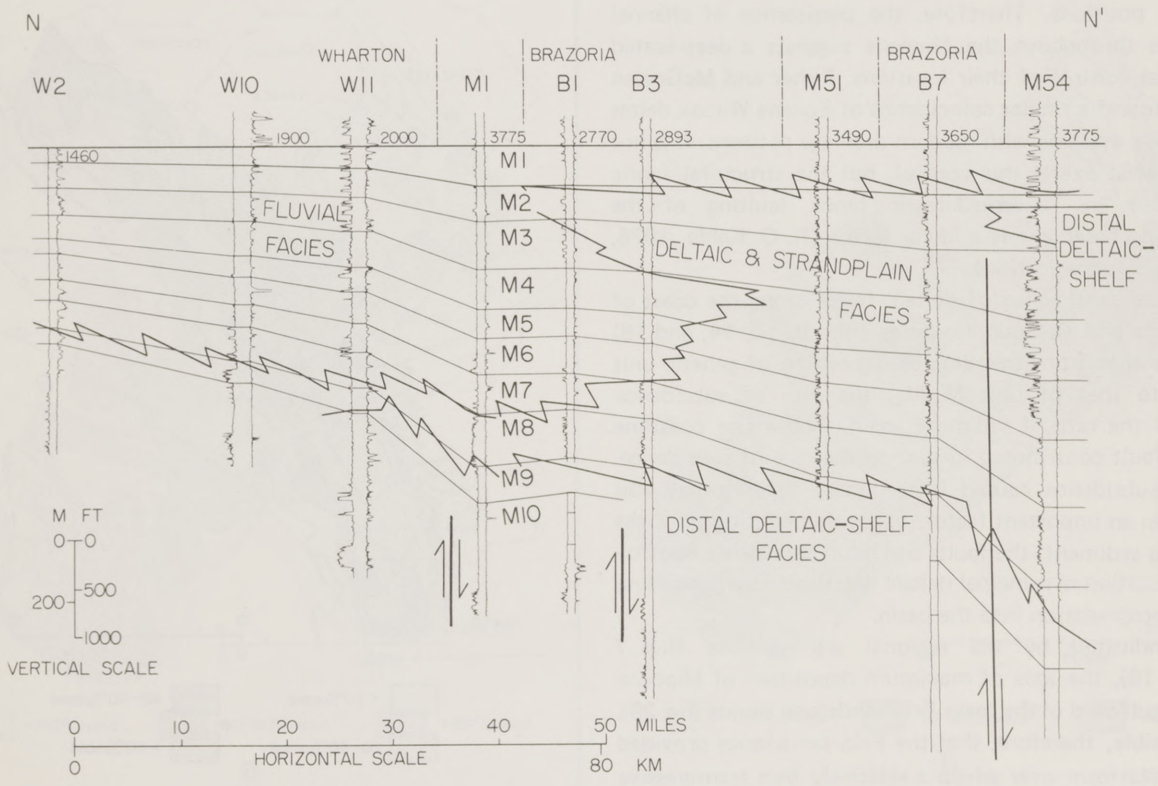


Figure 10. Stratigraphic dip section N-N' showing fluvial and deltaic facies and faults, Miocene high-destructive delta system, Middle Texas Coast. Datum is correlation horizon M_1. Depth values are in feet.

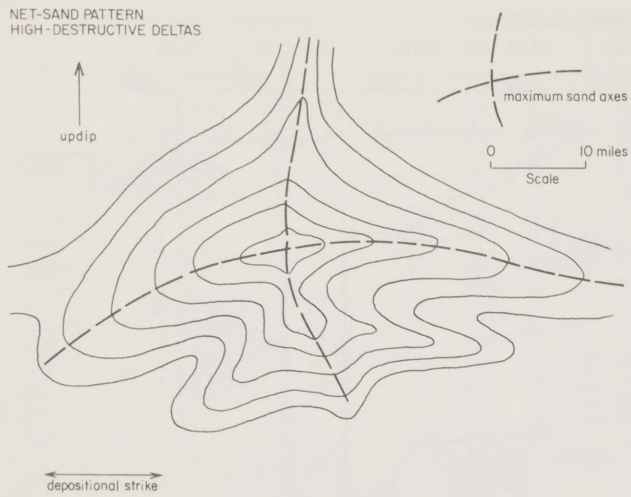


Figure 11. Idealized net-sand pattern for high-destructive deltas (from Fisher and others, 1969).

the greater compaction of interchannel muds relative to channel sands should tend to displace subsequent channels laterally, thereby producing an offset vertical arrangement (Brown, 1969). Vertical stacking or superposition of channel-fill sands suggests that subsidence maintains the channel positions. Therefore, the persistence of channel positions throughout the Miocene suggests a deep-seated structural control of their locations. Fisher and McGowen (1969) found a similar coincidence of Eocene Wilcox deltas and fluvial systems with modern drainage patterns. It is not certain what exerts this control, but the structural fabric introduced by Triassic-Jurassic block faulting of the underlying basement is a likely factor (R. O. Kehle, 1976, personal communication).

Vertical persistence of deltaic facies along the coast of Matagorda and Calhoun Counties (figs. 9, 10, 14, and 18) indicates that from the time of deposition of genetic unit M_7-M_8 to that of unit M_3-M_4, the rate of subsidence matched the rate of sediment input. The major coastline growth fault contributed in part to the rate of subsidence. Crustal subsidence caused by sediment loading may also have been an important factor. In accommodating all of the incoming sediment, the faults and basin subsidence controlled the location of principal deltaic deposition by preventing further progradation into the basin.

As indicated by the regional dip sections (figs. 7 through 10), the axis of maximum deposition of Miocene sands is gulfward of the main Frio sandstone trends (fig. 29). It is possible, therefore, that the Frio sandstones provided a stable platform over which a relatively thin transgressive Anahuac section was deposited. Significant growth faulting caused by differential compaction occurs only where the Miocene sands prograded onto thick Frio shales gulfward of the Frio sandstone trend.

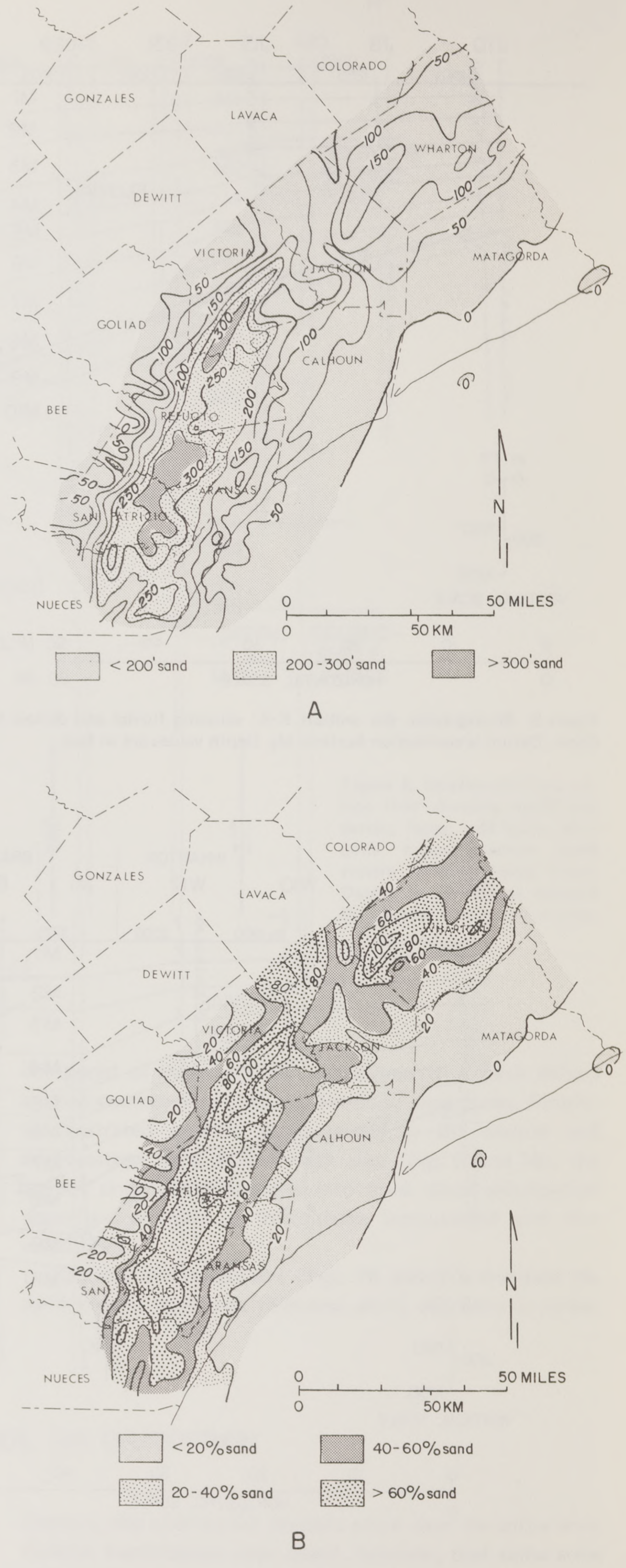


Figure 12. Genetic unit M_9-M_{10}, Miocene, Middle Texas Coast: A. net-sandstone thickness (contour interval equals 50 feet), B. sandstone percent (contour interval equals 20 percent).

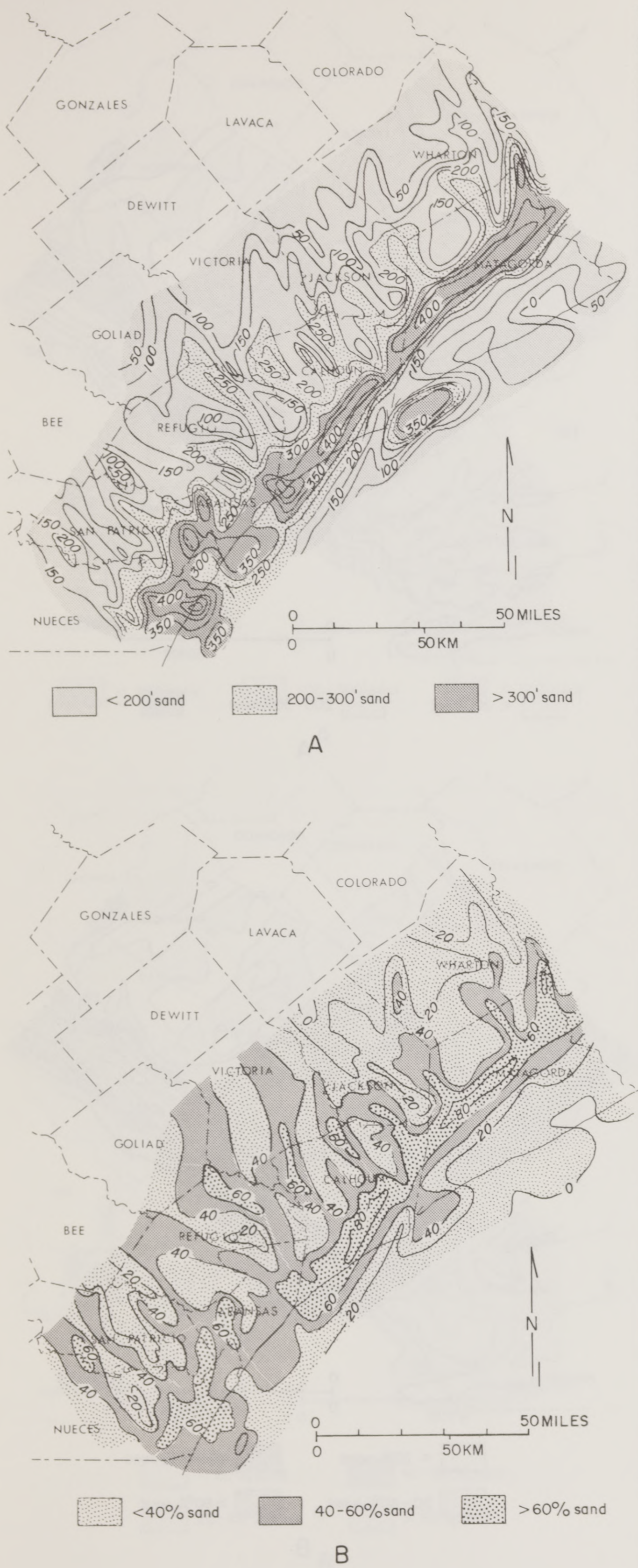


Figure 13. Genetic unit M_8-M_9, Miocene, Middle Texas Coast: A. net-sandstone thickness (contour interval equals 50 feet), B. sandstone percent (contour interval equals 20 percent).

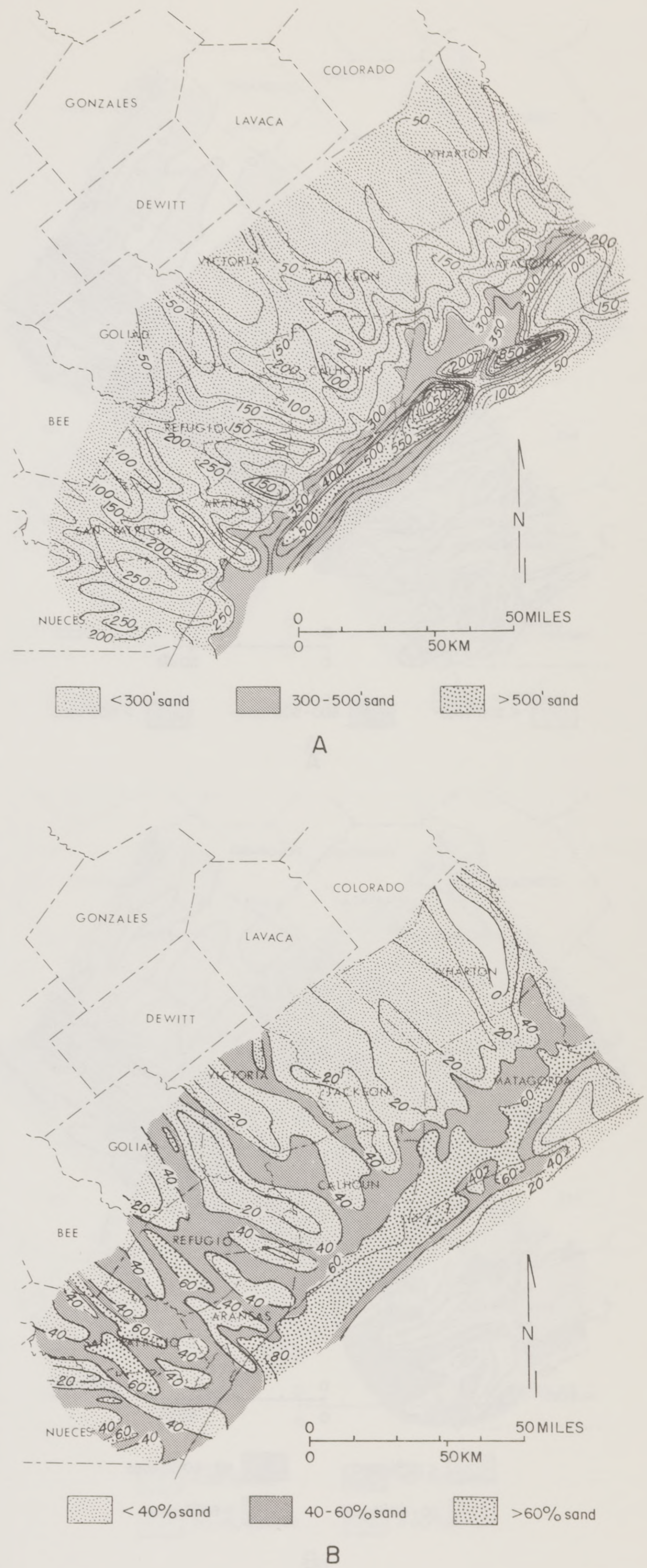


Figure 14. Genetic unit M_7-M_8, Miocene, Middle Texas Coast: A. net-sandstone thickness (contour interval equals 50 feet), B. sandstone percent (contour interval equals 20 percent).

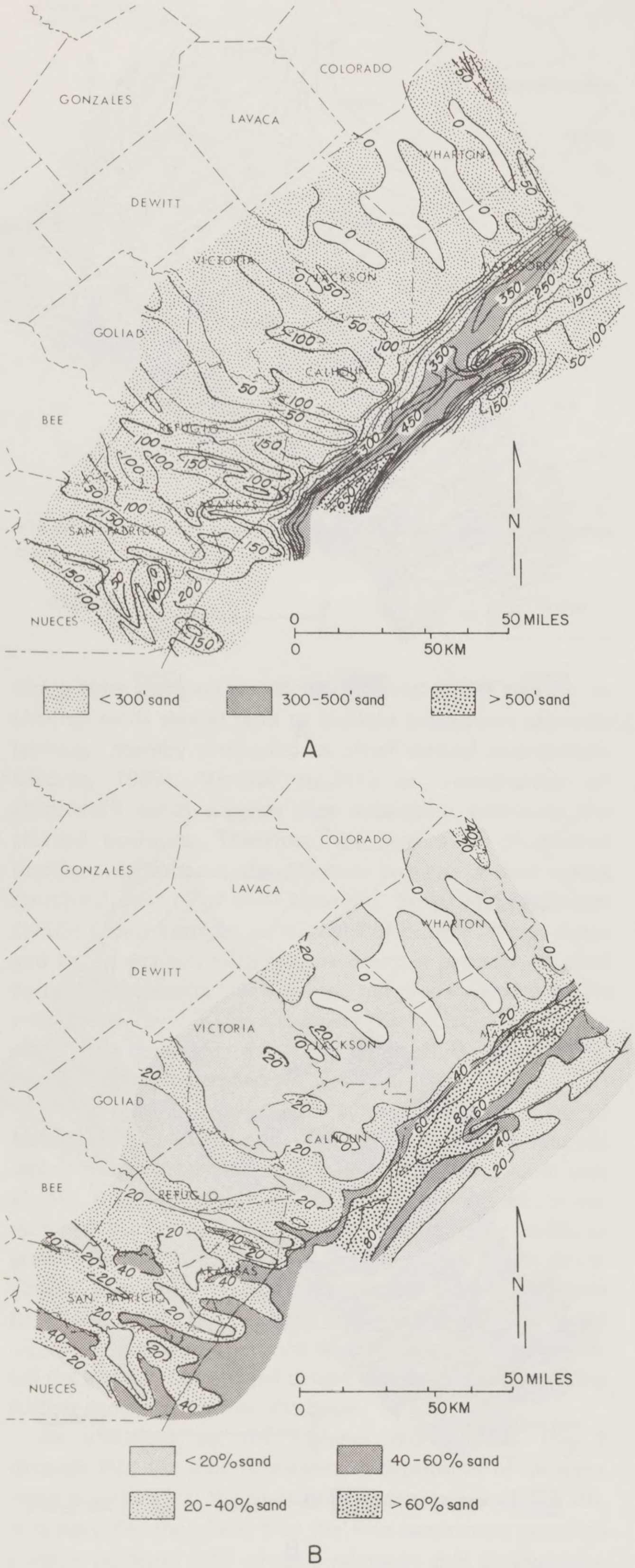


Figure 15. Genetic unit M_6-M_7, Miocene, Middle Texas Coast: A. net-sandstone thickness (contour interval equals 50 feet), B. sandstone percent (contour interval equals 20 percent).

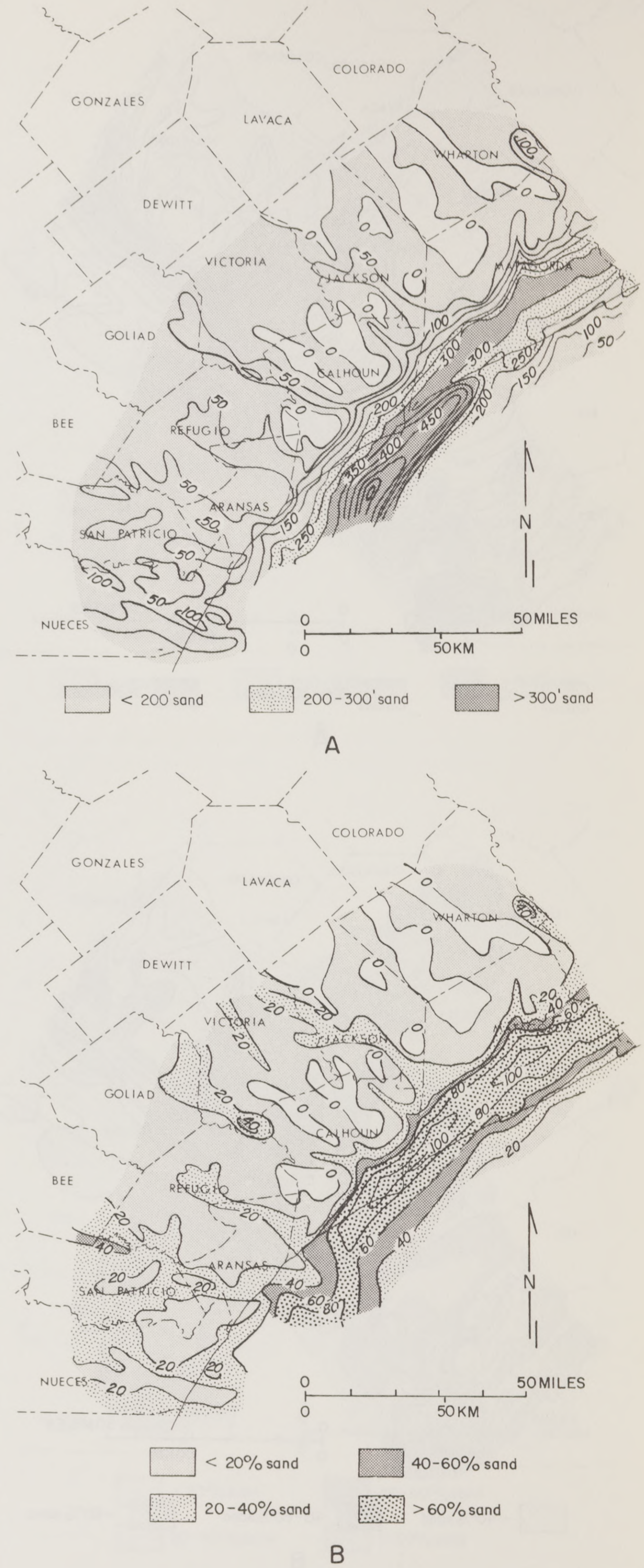


Figure 16. Genetic unit M_5-M_6, Miocene, Middle Texas Coast: A. net-sandstone thickness (contour interval equals 50 feet), B. sandstone percent (contour interval equals 20 percent).

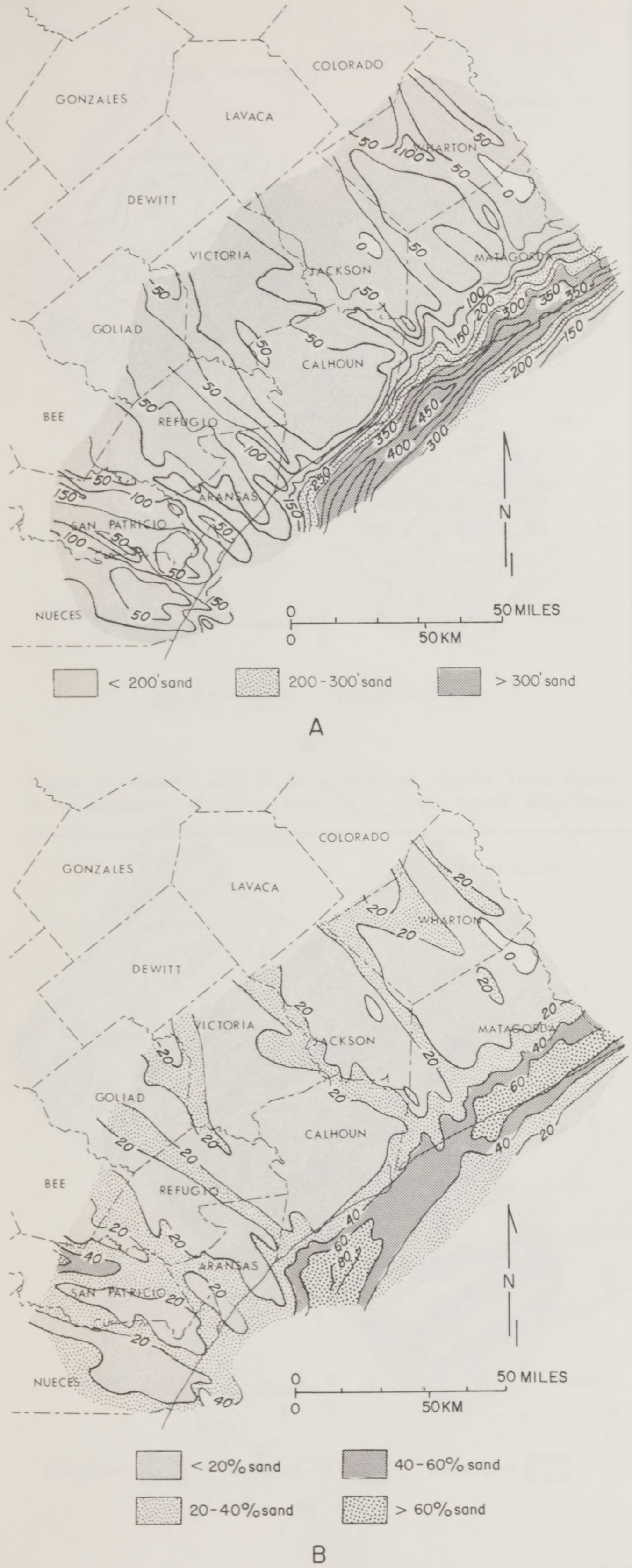


Figure 17. Genetic unit M_4-M_5, Miocene, Middle Texas Coast: A. net-sandstone thickness (contour interval equals 50 feet), B. sandstone percent (contour interval equals 20 percent).

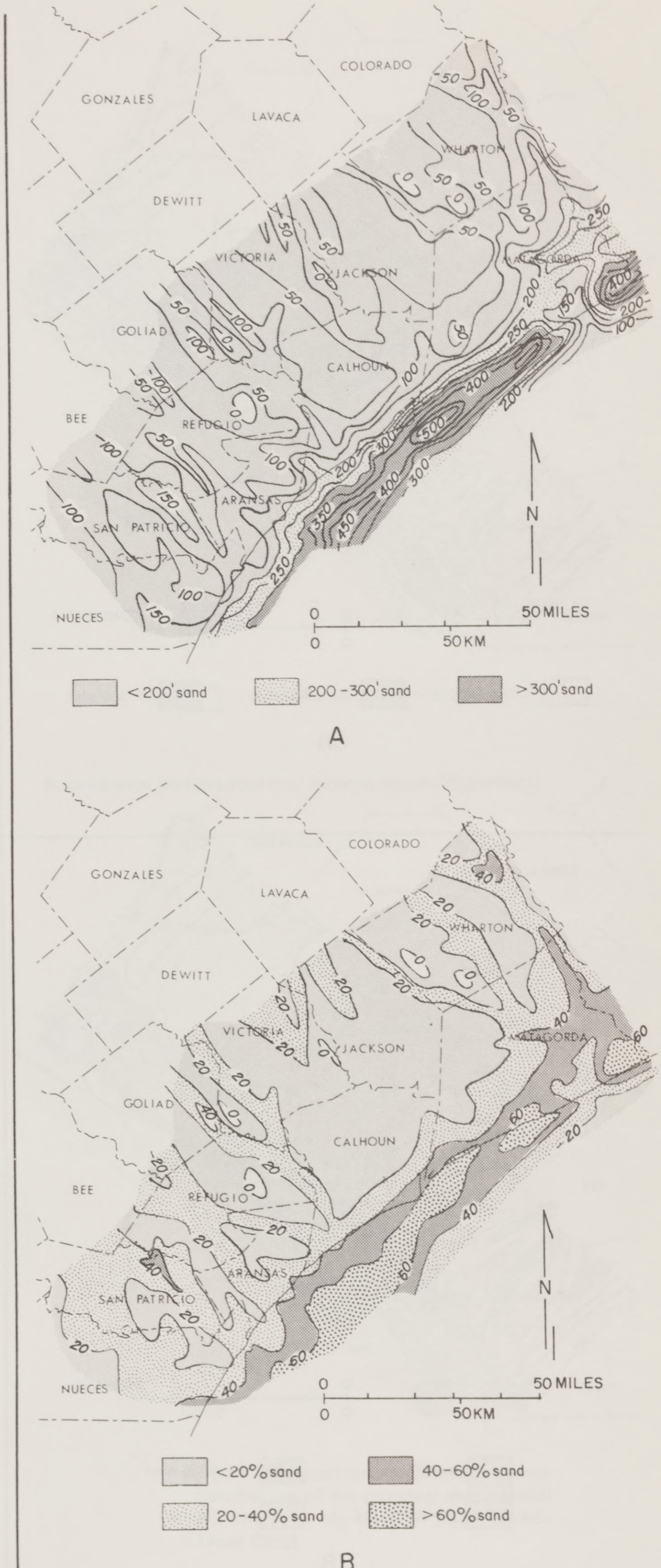


Figure 18. Genetic unit M_3-M_4, Miocene, Middle Texas Coast: A. net-sandstone thickness (contour interval equals 50 feet), B. sandstone percent (contour interval equals 20 percent).

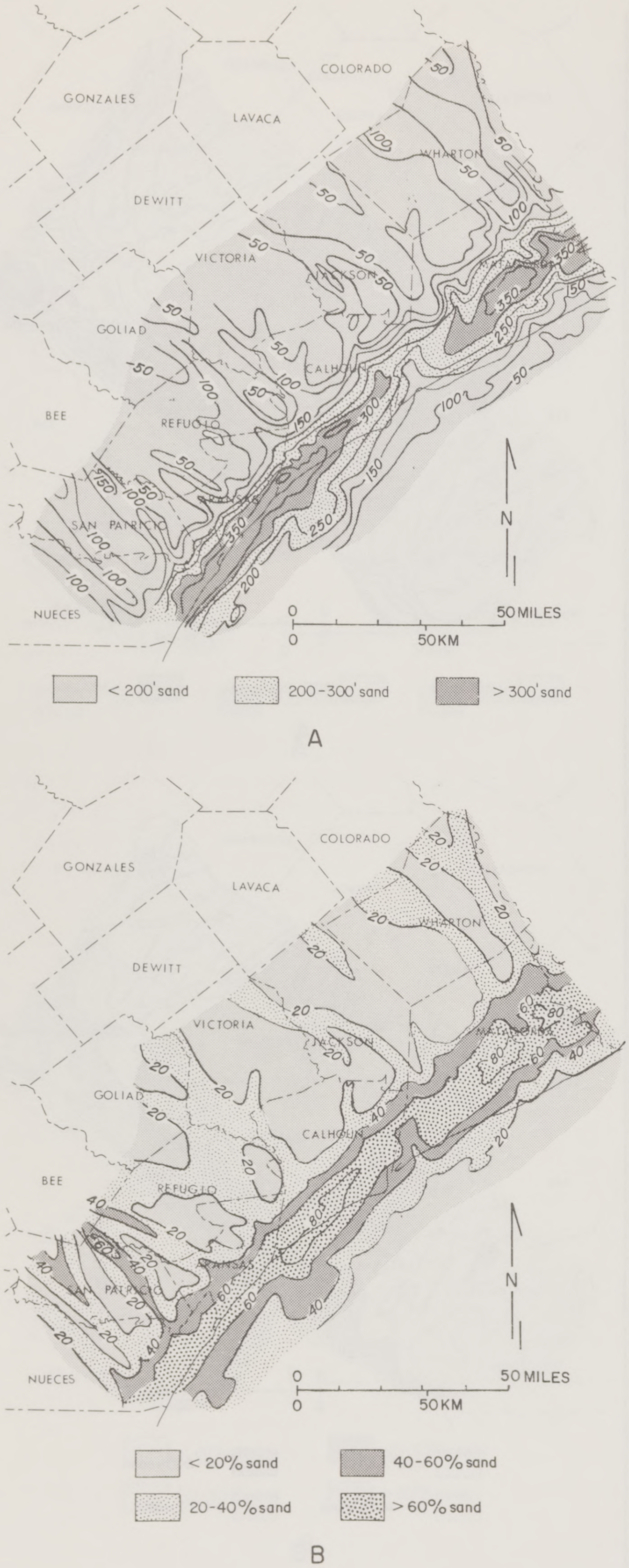


Figure 19. Genetic unit M_2-M_3, Miocene, Middle Texas Coast: A. net-sandstone thickness (contour interval equals 50 percent), B. sandstone percent (contour interval equals 20 percent).

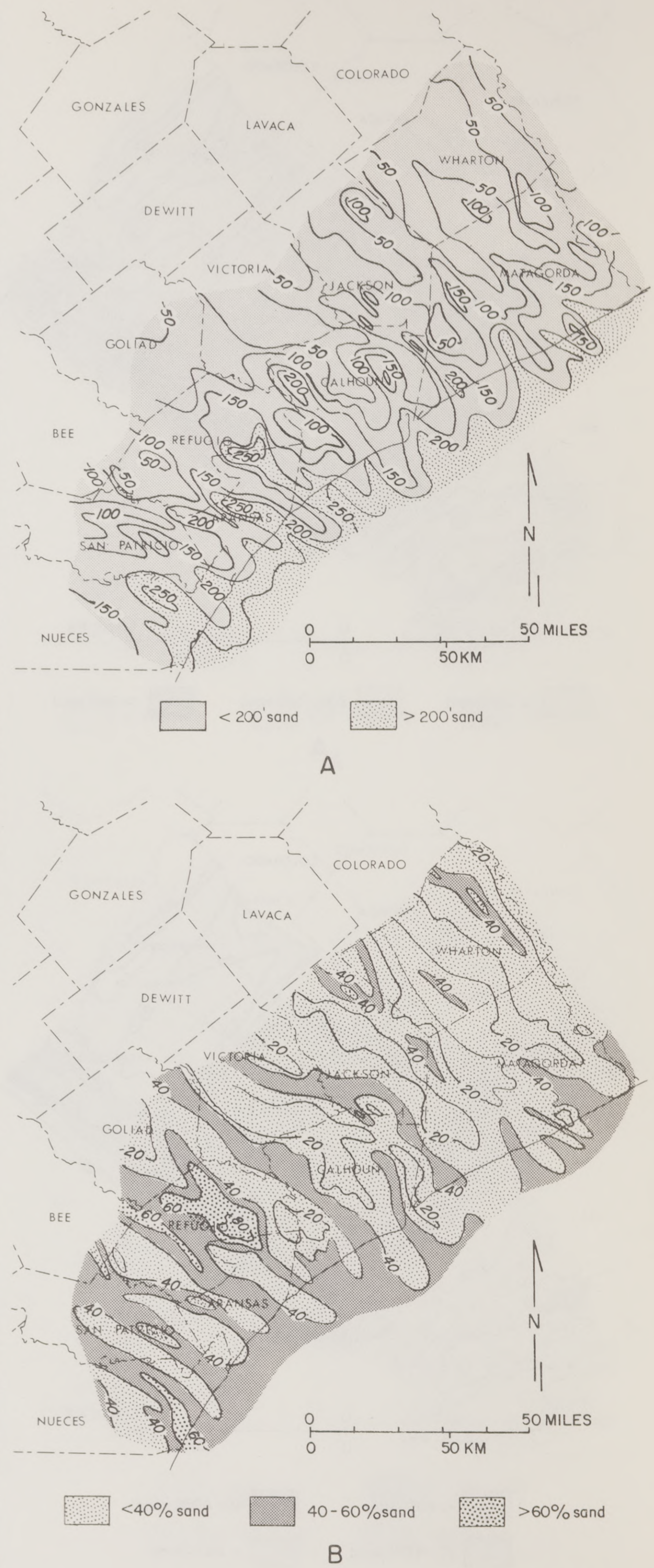
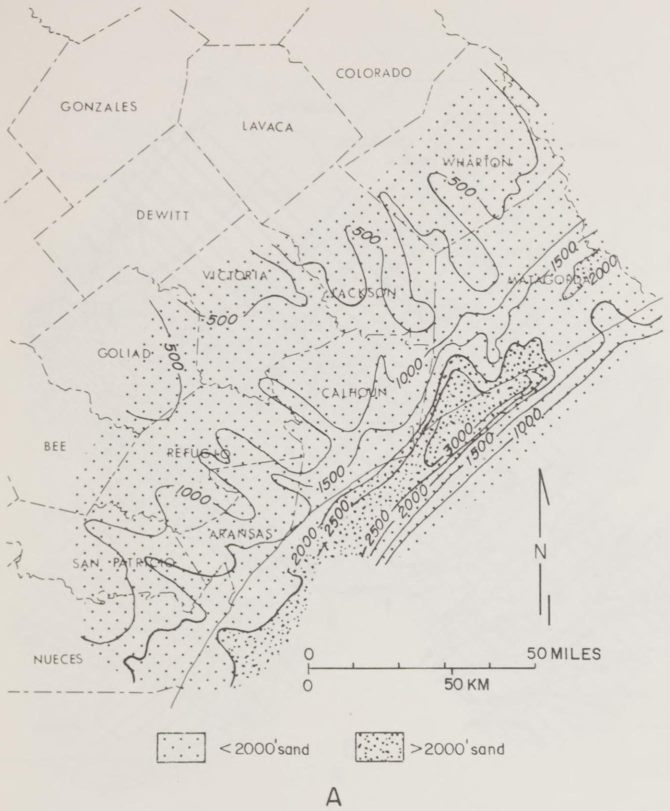


Figure 20. Genetic unit M_1-M_2, Miocene, Middle Texas Coast: A. net-sandstone thickness (contour interval equals 50 feet), B. sandstone percent (contour interval equals 20 percent).



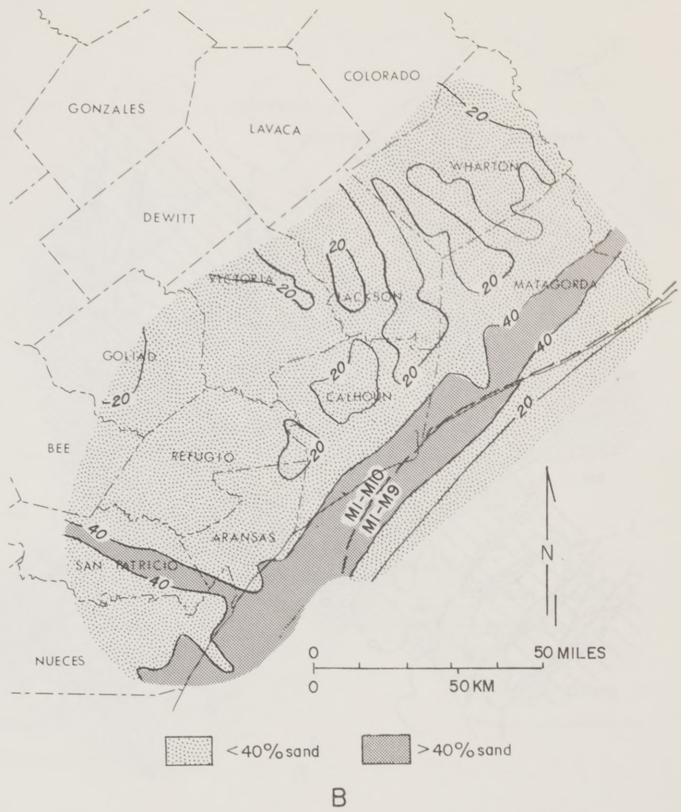


Figure 21. Genetic unit M_1-M_{10}, Miocene, Middle Texas Coast: A. net-sandstone thickness (contour interval equals 500 feet), B. sandstone percent (contour interval equals 20 percent).

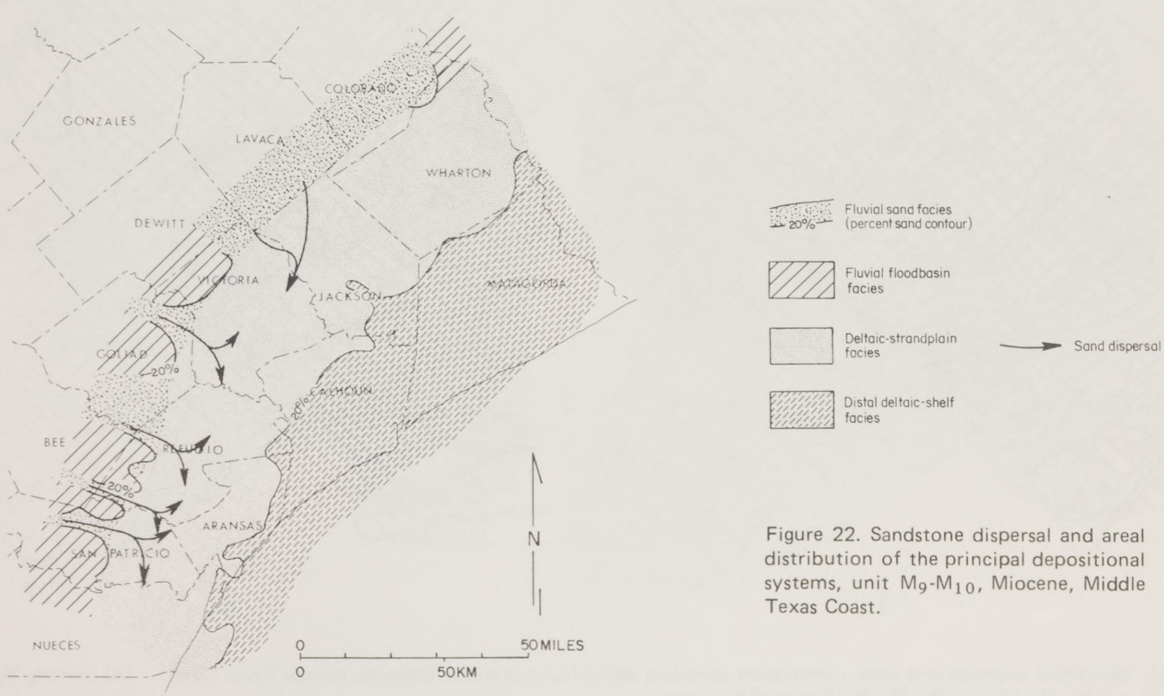


Figure 22. Sandstone dispersal and areal distribution of the principal depositional systems, unit M_9-M_{10}, Miocene, Middle Texas Coast.

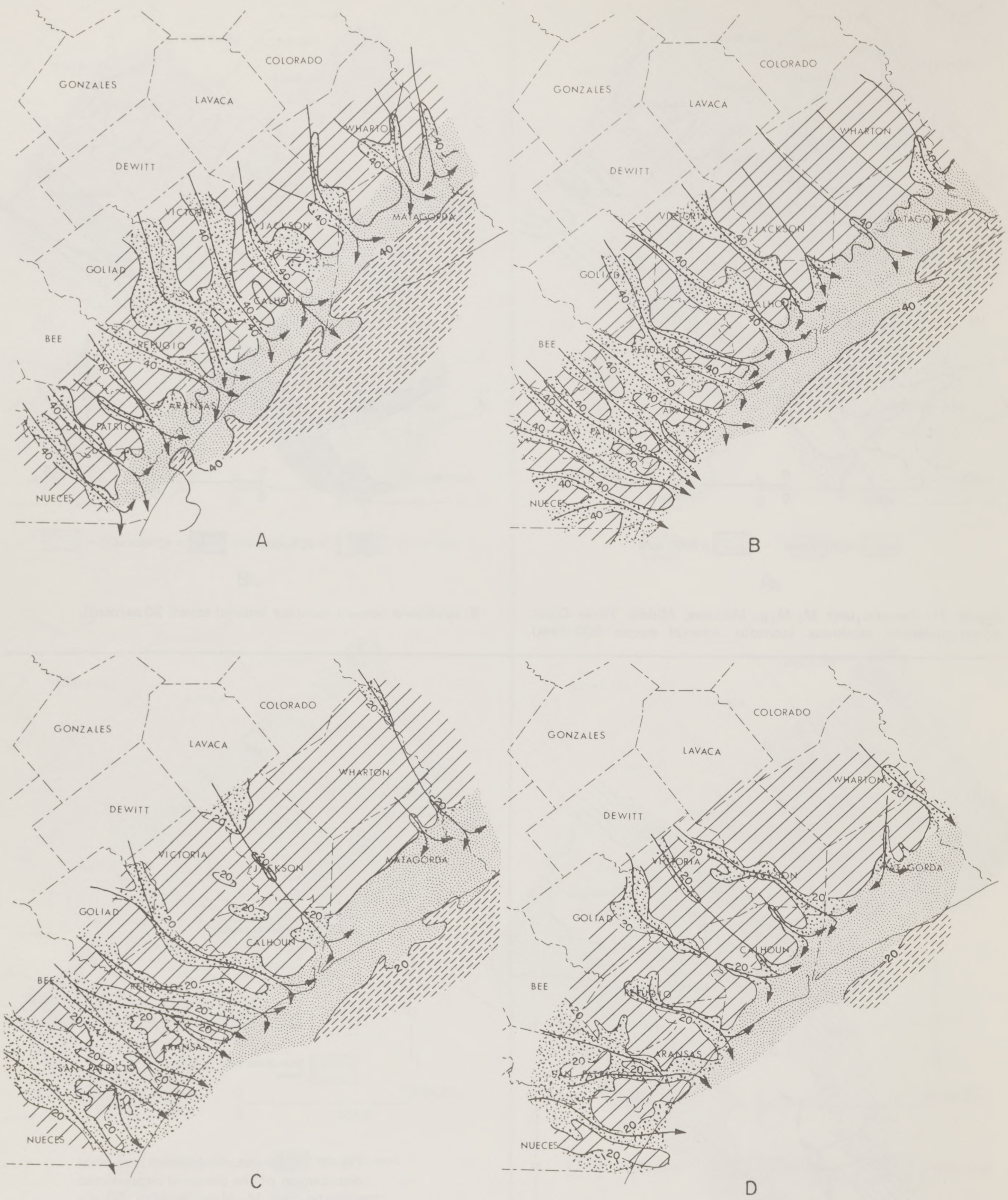


Figure 23. Sandstone dispersal and areal distribution, principal depositional systems, Miocene, Middle Texas Coast: (A) unit M_8-M_9, (B) unit M_7-M_8, (C) unit M_6-M_7, (D) unit M_5-M_6. See figure 22 for legend.

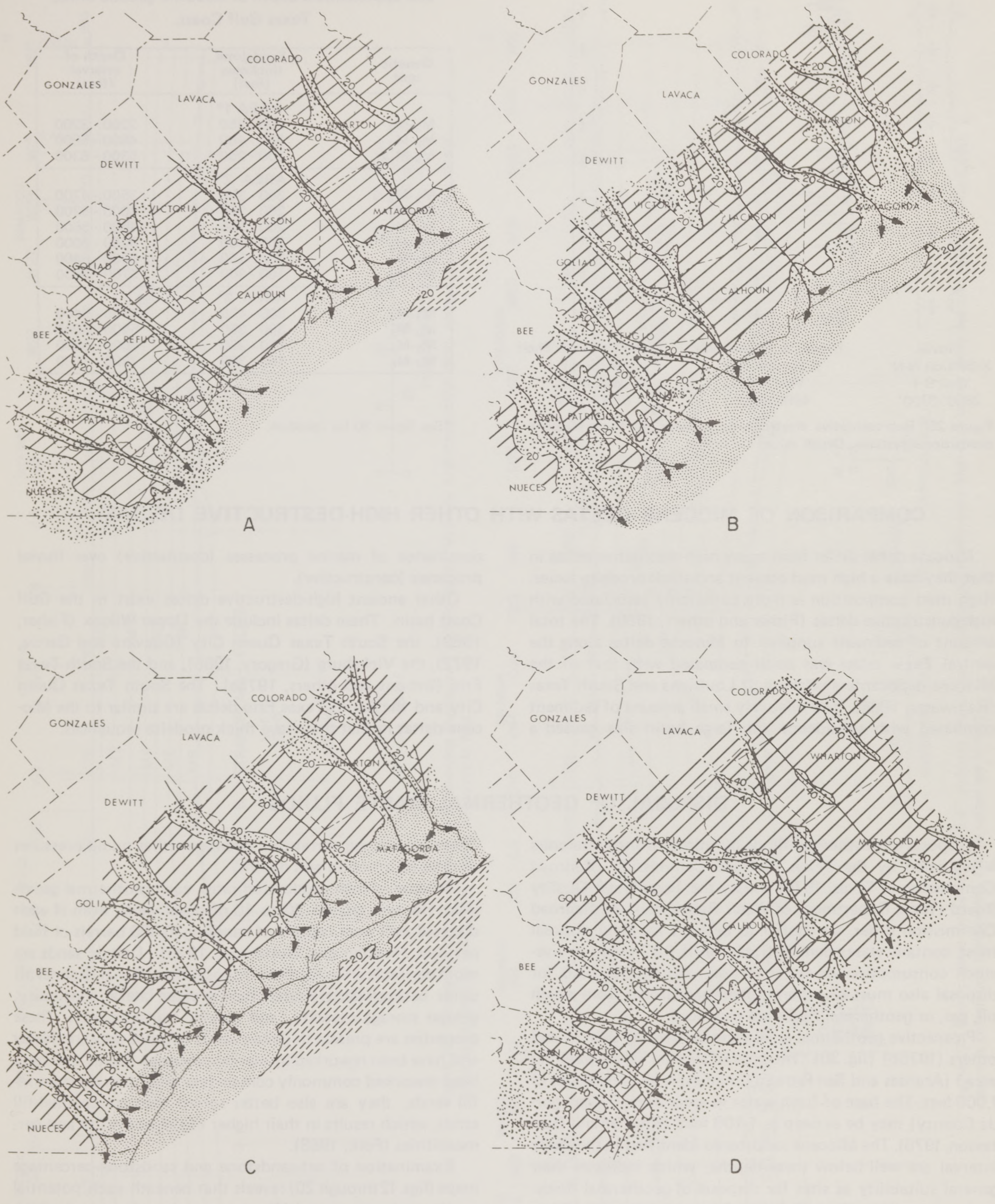
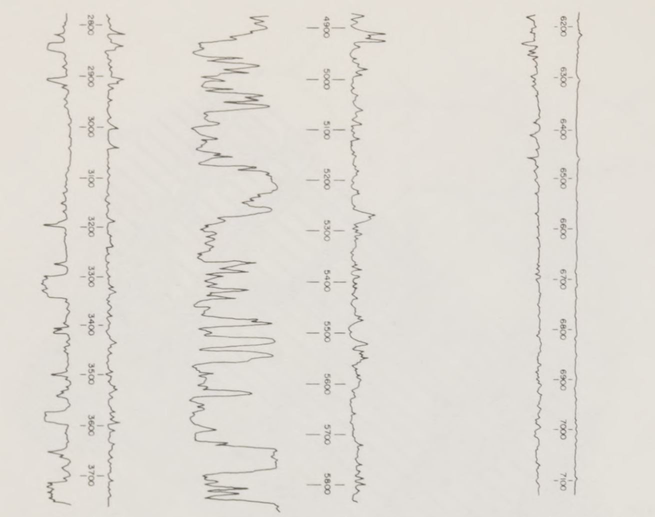


Figure 24. Sandstone dispersal and areal distribution, principal depositional systems, Miocene, Middle Texas Coast: (A) unit M_4-M_5, (B) unit M_3-M_4, (C) unit M_2-M_3, (D) unit M_1-M_2. See figure 22 for legend.



Fluvial	Deltaic & Strandplain	Distal Deltaic & Shelf
X-Section N-N′	X-Section N-N′	X-Section E-E′
Well B-1	Well M-54	Well M-45
2800′-3700′	4900′-5800′	6200′-7100′

Figure 25. Representative electrical-log patterns for three Miocene depositional systems. Depth values are in feet.

Table 1. Cumulative sandstone thickness and approximate depth of Miocene genetic units, Texas Gulf Coast.

Genetic unit	Sandstone thickness (feet)	Depth of interval (feet)
	AREA 1*	
M_2-M_3	200 - 350	2200 - 3200
M_8-M_9	300 - 400	4800 - 5800
M_9-M_{10}	100 - 250	5300 - 6300
	AREA 2*	
M_2-M_3	300 - 350	3500 - 4700
M_3-M_4	200 - 250	4000 - 5200
M_4-M_5	200 - 350	4500 - 5600
M_5-M_6	250 - 300	5000 - 6000
M_6-M_7	250 - 350	5300 - 6400
M_7-M_8	100 - 300	5700 - 6800
	AREA 3*	
M_3-M_4	300 - 450	4700 - 5400
M_4-M_5	300 - 350	5400 - 6000
M_5-M_6	150 - 200	6000 - 6600
M_7-M_8	150 - 300	7300 - 8100

*See figure 30 for location.

COMPARISON OF MIOCENE DELTAS WITH OTHER HIGH-DESTRUCTIVE DELTAS

Miocene deltas differ from many high-destructive deltas in that they have a high mud content and thick prodelta facies. High mud composition is more commonly associated with high-constructive deltas (Fisher and others, 1969). The total amount of sediment supplied to Miocene deltas along the central Texas coast was small compared with that of the Miocene depocenters offshore of Louisiana and South Texas (Rainwater, 1964). The relatively small amount of sediment combined with subsidence and large basin size caused a dominance of marine processes (destructive) over fluvial processes (constructive).

Other ancient high-destructive deltas exist in the Gulf Coast basin. These deltas include the Upper Wilcox (Fisher, 1969), the South Texas Queen City (Guevara and Garcia, 1972), the Vicksburg (Gregory, 1966), and the South Texas Frio (Bebout and others, 1975a). The South Texas Queen City and the South Texas Frio deltas are similar to the Miocene deltas in that they have thick prodelta sequences.

DISPOSAL OF GEOTHERMAL WASTE FLUIDS

Disposal of geothermal fluids by injection into reservoirs is regulated by the Texas Railroad Commission (Railroad Commission of Texas, 1975) and by the Texas Water Quality Board (Texas Department of Water Resources). By Railroad Commission order, an aquifer to be used for fluid disposal must contain water demonstrably unfit for human or livestock consumption or for irrigation. An aquifer used for disposal also must be separate from sandstones from which oil, gas, or geothermal fluids are produced.

Prospective geothermal areas were defined by Bebout and others (1975b) (fig. 30). The base of slightly saline water in area 1 (Aransas and San Patricio Counties) is above a depth of 1,000 feet. The base of fresh water in areas 2 and 3 (Matagorda County) may be as deep as 1,100 feet (Kreitler and Gustavson, 1976). The Miocene sandstones identified in the study interval are well below these depths, which indicates their general suitability as sites for disposal of geothermal fluids.

Data on disposal of oil-field brines at depths of 1,480 to 7,120 feet in Matagorda County are available (Hammond, 1969). Injection rates range from 40 to 10,000 barrels of water per day with pump pressures from 0 to 1,000 psi. There is no strong correlation between either pump pressures or rates of injection and depth.

Because of high production rates, each geothermal generating site will require 20 to 40 disposal wells, even if each disposal well were capable of handling 10,000 barrels of fluid per day (Kreitler and Gustavson, 1976). Deltaic sands are more desirable areas for fluid disposal than fluvial channel-fill sands because deltaic sands have greater lateral continuity, greater storage capacity, and greater transmissivity. These properties are present in deltaic sands because they are thicker and have been reworked by marine processes. Sands that have been reworked commonly contain less mud than do channel-fill sands; they are also better sorted than are channel-fill sands, which results in their higher initial porosities and permeabilities (Folk, 1968).

Examination of net-sandstone and sandstone-percentage maps (figs. 12 through 20) reveals that beneath each potential geothermal area several Miocene genetic units contain thick deltaic sandstone reservoirs. Cumulative sandstone thickness and approximate depth of the selected units for each prospective geothermal area are listed in table 1.

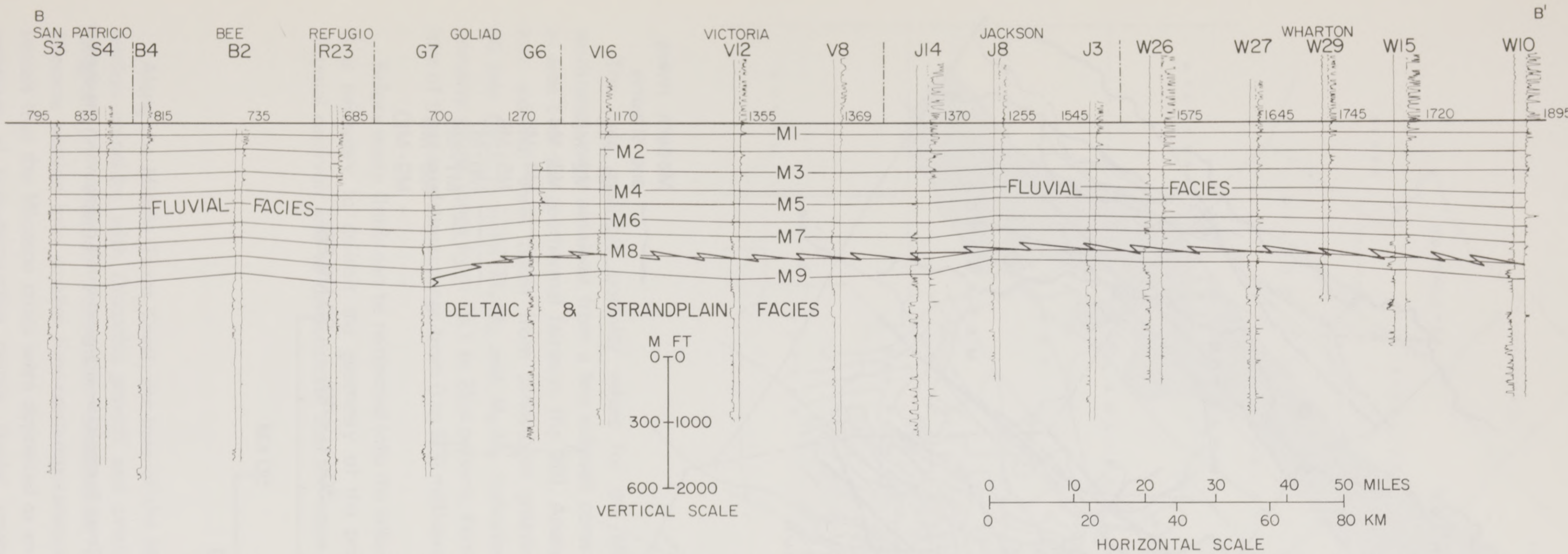


Figure 26. Stratigraphic strike section B-B′ showing fluvial and deltaic facies, Miocene high-destructive delta system, Middle Texas Coast. Datum is correlation horizon M_1. Depth values are in feet.

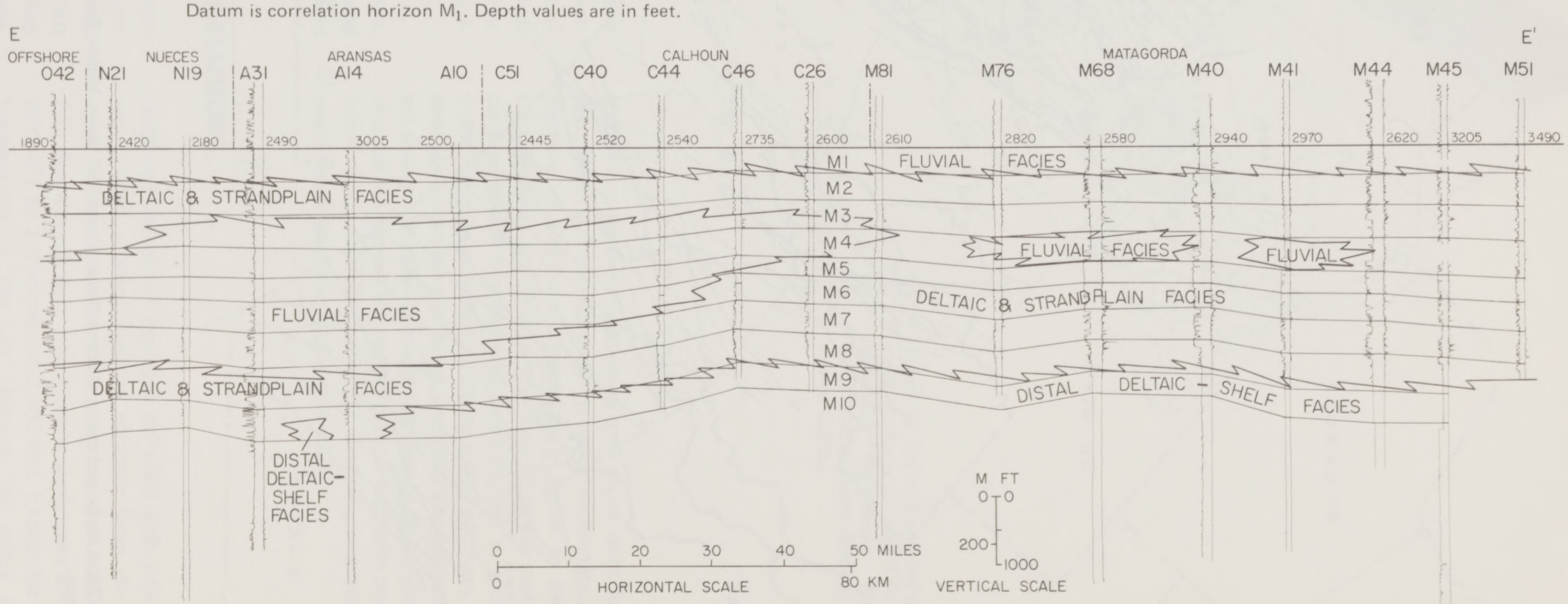


Figure 27. Stratigraphic strike section E-E′ showing fluvial and deltaic facies, Miocene high-destructive delta system, Middle Texas Coast. Datum is correlation horizon M_1. Depth values are in feet.

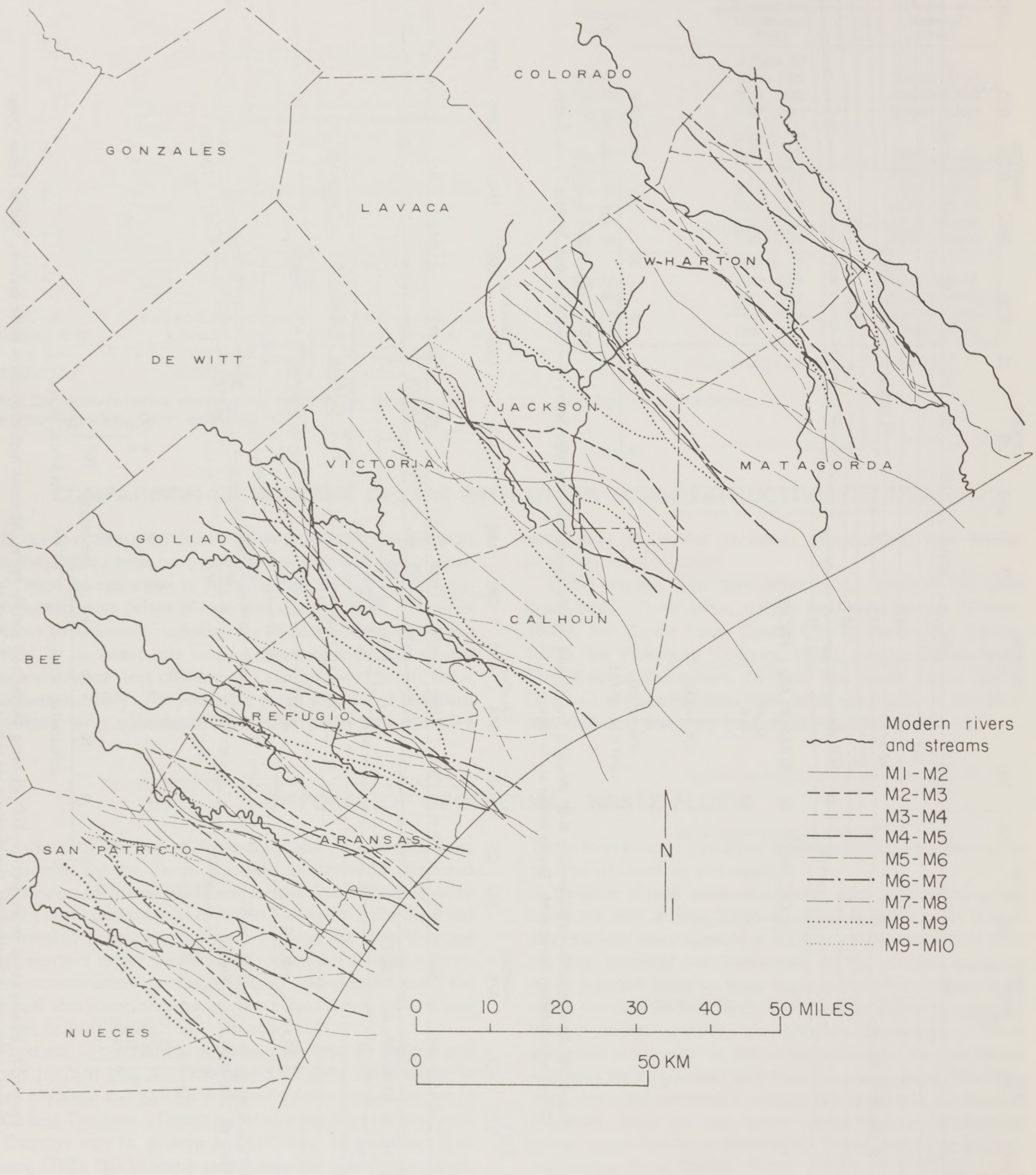


Figure 28. Location of major Miocene fluvial channel-fill facies, Middle Texas Coast. Symbols identify genetic unit during which the channel was active.

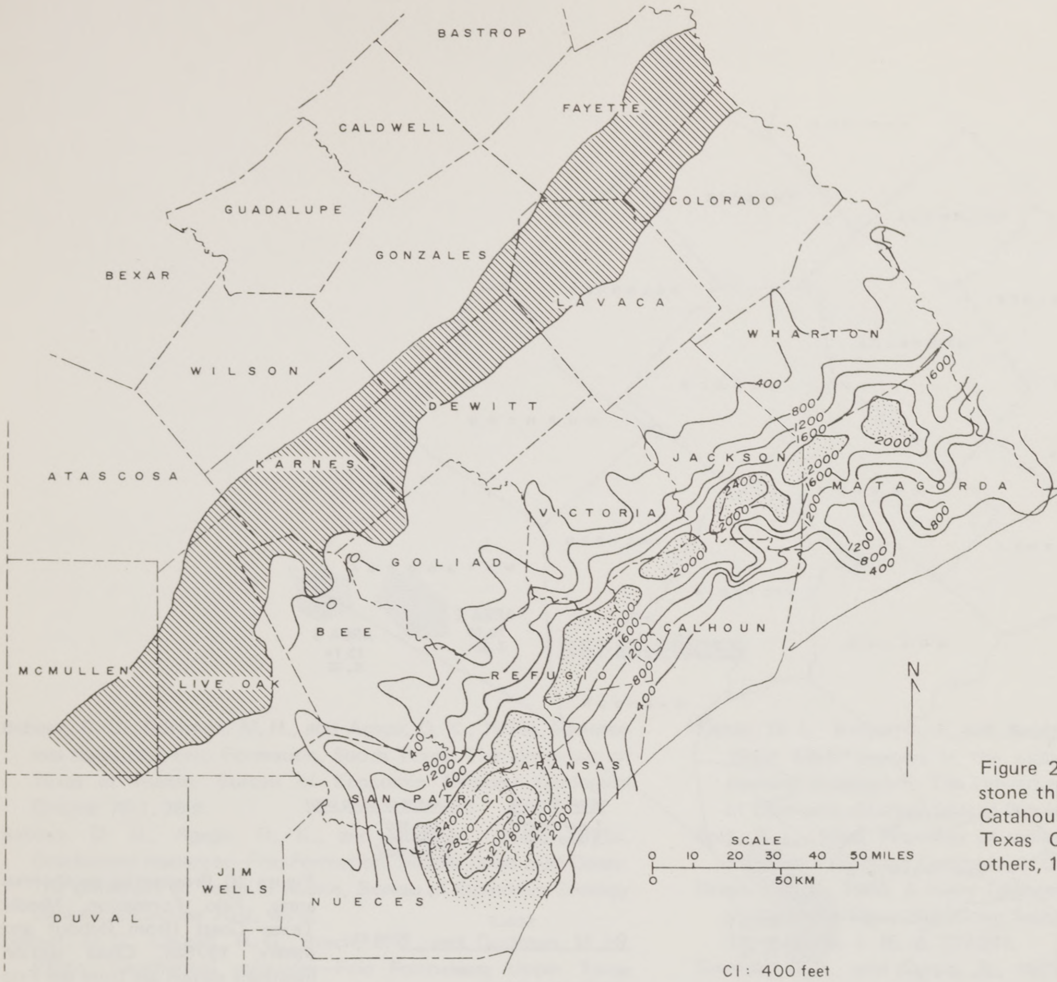


Figure 29. Outcrop and net-sandstone thickness for total Frio and Catahoula Formations, Middle Texas Coast (from Bebout and others, 1975b).

The only available porosity values for the Miocene sandstones were obtained from a few sidewall cores taken in area 1 of the geothermal fairways (fig. 30). Analyses of four sidewall cores taken from sandstones greater than 30 feet thick in units M_7-M_8 and M_8-M_9 indicated that porosity values range from 16.1 to 28.4 percent. Permeabilities of these sandstones range from 0 to 509 millidarcys.

Before waste fluids can be reinjected into the subsurface, it is necessary to delimit the geometry of the proposed disposal reservoir and to demonstrate that the waste would remain in a reservoir containing only water unfit for other uses. Meeting these requirements would necessitate detailed mapping of individual sandstones in order to determine their geometry and to show that they are not in stratigraphic continuity with producing zones of oil, gas, or geothermal fluids. Detailed structural mapping is also necessary both to determine the extent to which potential disposal sandstones are arranged in separate fault blocks and to demonstrate that disposal sandstones are not in fault contact with unsuitable zones. Such detailed site-specific mapping requires denser well control than was used in this study.

CONCLUSIONS

Along the Middle Texas Coast, the base of the Miocene section coincides with *Discorbis gravelli* and overlies the Oligocene(?) Anahuac Formation. Subdivision of the Miocene section into smaller time-contemporaneous units reveals that the Miocene strata were deposited as an offlap sequence of high-destructive deltaic, fluvial, strandplain, and shelf sediments. The axis of maximum Miocene sandstone deposition migrated gulfward with time until it was located a short distance offshore from the present coast. There, the deltas stabilized seaward of the Oligocene Frio depositional axis, and Miocene sandstones are stacked vertically to a thickness of 3,000 feet. Except for a minor transgression in the late Miocene, the entire sequence prograded progressively gulfward across the Miocene shelf.

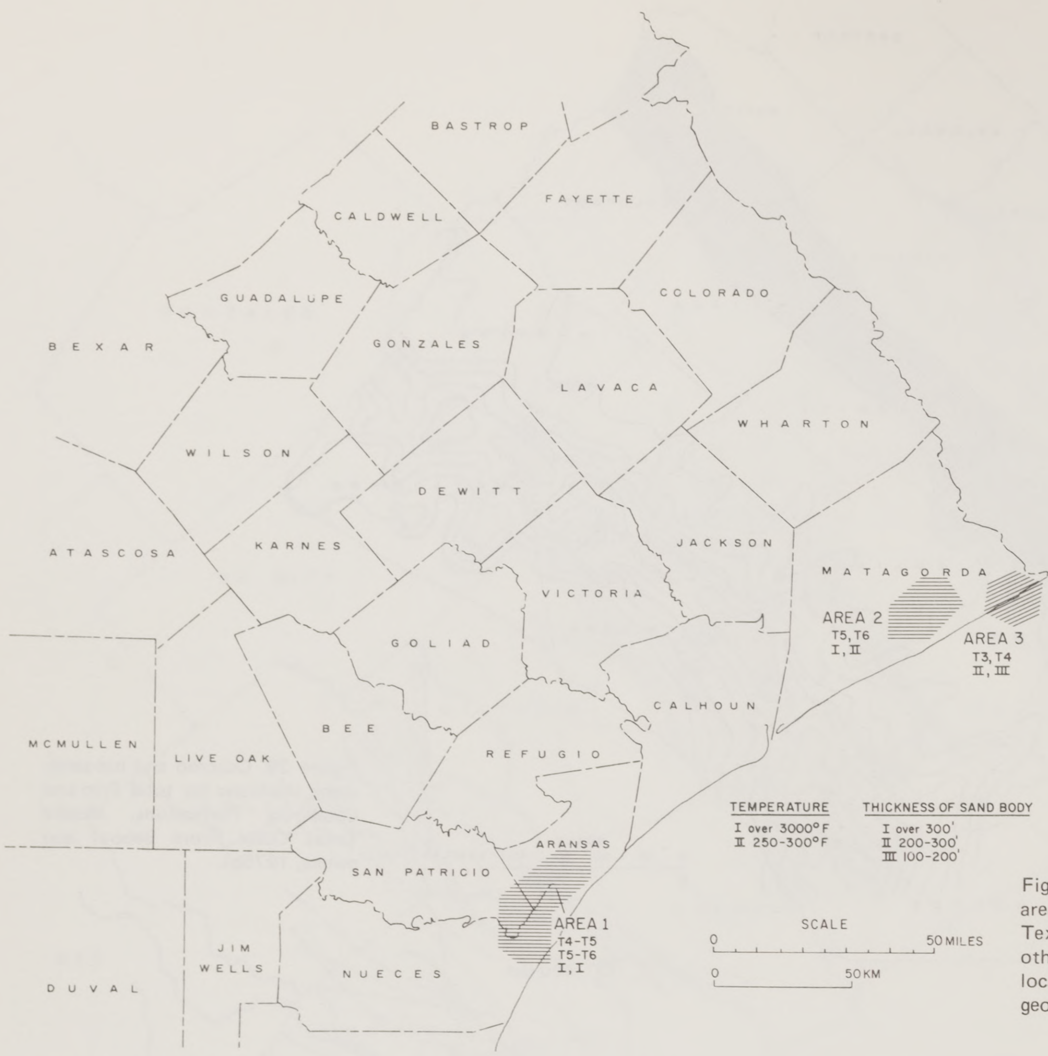


Figure 30. Prospective geothermal areas, Frio Formation, Middle Texas Coast (from Bebout and others, 1975b). Cross section locations shown are from the Frio geothermal energy study.

Distinctive sandstone distribution and electrical-log characteristics allow the recognition of three depositional systems for each genetic unit except M_1-M_2.

The systems are

1. Fluvial system composed of floodbasin shale and dip-oriented fluvial sandstone facies.
2. High-destructive, wave-dominated deltaic and strandplain system composed of shales and thick strike-aligned shoreface sand facies exhibiting subordinate dip orientation produced by limited progradation at river mouths.
3. Distal deltaic-shelf system composed of thin distal deltaic-strandplain facies separating thick prodelta and shelf mud facies.

Only the fluvial system is identified in unit M_1-M_2 because the deltaic facies are gulfward of the study area.

Depositional patterns of Miocene sandstones indicate that deposition was controlled to some extent by structural features. Persistence of the channel positions from unit to unit suggests deep-seated structural control. Similarly, deltaic environments in units between horizons M_7 and M_8 were stabilized (localized) by the large growth faults parallel to and immediately updip of the main sand trends and/or by rapid subsidence of the crust in the area of principal deposition.

Miocene sandstones are prospective reservoirs for disposal of geothermal waste fluids. Each geothermal prospect is underlain by three to six Miocene genetic units that are potentially suitable for waste disposal. The entire Miocene sequence in these geothermal fairways occurs at sufficient depth to satisfy requirements of the Texas Railroad Commission for injection of waste fluids.

REFERENCES

Bebout, D. G., Dorfman, M. H., and Agagu, O. K., 1975a, Geothermal resources—Frio Formation, South Texas: The University of Texas at Austin, Bureau of Economic Geology Geological Circular 75-1, 36 p.

Bebout, D. G., Agagu, O. K., and Dorfman, M. H., 1975b, Geothermal resources—Frio Formation, Middle Texas Gulf Coast: The University of Texas at Austin, Bureau of Economic Geology Geological Circular 75-8, 43 p.

Bebout, D. G., Loucks, R. G., Bosch, S. C., and Dorfman, M. H., 1976a, Geothermal resources—Frio Formation, Upper Texas Gulf Coast: The University of Texas at Austin, Bureau of Economic Geology Geological Circular 76-3, 47 p.

Bebout, D. G., Luttrell, P. E., and Seo, J. H., 1976b, Regional Tertiary cross sections—Texas Gulf Coast: The University of Texas at Austin, Bureau of Economic Geology Geological Circular 76-5, 10 p.

Bebout, D. G., Loucks, R. G., and Gregory, A. R., 1978, Frio sandstone reservoirs in the deep subsurface along the Texas Gulf Coast: The University of Texas at Austin, Bureau of Economic Geology Report of Investigations 91, 92 p.

Brown, L. F., Jr., 1969, Geometry and distribution of fluvial and deltaic sandstones (Pennsylvanian and Permian), North-Central Texas: Gulf Coast Association Geological Societies Transactions, v. 19, p. 23-47, *reprinted as* The University of Texas at Austin, Bureau of Economic Geology Geological Circular 69-4.

Bruce, C. H., 1973, Pressured shale and related sediment deformation: A mechanism for development of regional contemporaneous faults: American Association of Petroleum Geologists Bulletin, v. 57, no. 5, p. 878-886.

Busch, D. A., 1971, Genetic units in delta prospecting: American Association of Petroleum Geologists Bulletin, v. 55, no. 8, p. 1137-1154.

Fisher, W. L., 1969, Facies characterization of Gulf Coast basin delta systems, with some Holocene analogues: Gulf Coast Association of Geological Societies Transactions, v. 19, p. 239-262.

Fisher, W. L., and McGowen, J. H., 1969, Depositional systems in Wilcox Group (Eocene) of Texas and their relation to occurrence of oil and gas: American Association of Petroleum Geologists Bulletin, v. 53, no. 1, p. 30-54.

Fisher, W. L., Brown, L. F., Jr., Scott, A. J., and McGowen, J. H., 1969, Delta systems in the exploration for oil and gas, A research colloquium: The University of Texas at Austin, Bureau of Economic Geology Special Publication, 212 p.

Folk, R. L., 1968, Petrology of sedimentary rocks: Austin, Texas, Hemphill Publishing Company, 170 p.

Gregory, J. L., 1966, A lower Oligocene delta in the subsurface of southeastern Texas: Gulf Coast Association of Geological Societies Transactions, v. 16, p. 227-241.

Guevara, E. H., and Garcia, R., 1972, Depositional systems and oil-gas reservoirs in the Queen City Formation (Eocene), Texas: Gulf Coast Association of Geological Societies Transactions, v. 22, p. 1-22, *reprinted as* The University of Texas at Austin, Bureau of Economic Geology Geological Circular 72-4, 12 p.

Hammond, W. W., Jr., 1969, Ground-water resources of Matagorda County, Texas: Texas Water Development Board Report 91, 163 p.

Kiatta, H. W., 1971, The stratigraphy and petroleum potential of the lower Miocene, offshore Galveston and Jefferson Counties, Texas:Gulf Coast Association of Geological Societies Transactions, v. 21, p. 257-270.

Kreitler, C. W., and Gustavson, T. C., 1976, Geothermal resources of the Texas Gulf Coast—Environmental concerns arising from the production and disposal of geothermal waters, 55 p., *in* Second geopressured geothermal energy conference, volume V, legal, institutional, and environmental: The University of Texas at Austin, Center for Energy Studies.

McCarthy, J. A., 1970, The Miocene trend of Calhoun and Matagorda Counties, Texas: Gulf Coast Association of Geological Societies Transactions, v. 20, p. 163-176.

Railroad Commission of Texas, 1975, Conservation rules and regulations, oil, gas, and geothermal resources: 185 p.

Rainwater, E. H., 1964, Regional stratigraphy of the Gulf Coast Miocene: Gulf Coast Association of Geological Societies Transactions, v. 14, p. 81-124.

Woodbury, H. O., Murray, I. B., Jr., Pickford, P. J., and Akers, W. H., 1973, Pliocene and Pleistocene depocenters, outer continental shelf, Louisiana and Texas: American Association of Petroleum Geologists Bulletin, v. 57, no. 12, p. 2428-2439.

APPENDIX—LIST OF WELLS PROVIDING DATA FOR CROSS SECTIONS AND MAPS

Aransas County

Operator	Fee and well number
1. Continental Oil Co.	#56 St. Charles Co.
2. Cities Service Oil Co.	#1 Tatton Ranch
3. Union Producing Co.	#10 Tatton
4. Union Producing Co.	#16 Tatton
5. Sun Oil Co.	#1 State Tract 363
6. Prairie Producing Co. and others	#1 State Tract 12
7. Western Natural Gas Co.	#9 St. Charles
8. Sun Oil Co.	#1 State Tract 385
9. Western Natural Gas Co.	#14 St. Charles
10. Brazos Oil and Gas Co.	#1 Mesquite Bay State Tract 26
11. Sunray DX Oil Co.	#1 State Tract 96
12. Neil E. Hanson	#1 State Tract 129
13. Getty Oil Co.	#1 State Tract 158
14. Phillips Petroleum Co.	#1 State Tract 163
15. Getty Oil Co. and others	#1 State Tract 119
16. Atlantic Refining Co.	#5 State Tract 71
17. Prairie Producing Co.	#1 State Tract 12
18. Chevron Oil Co.	#1 State Tract 125
19. Aluminum Co. of America	#1 State Tract 101
20. Aluminum Co. of America	#1 State Tract 100
21. Midwest Oil Corp.	#1 State Tract 122
22. Amerada Petroleum Corp.	#1 Bankers Mortgage
23. Oil and Gas Property Management	#2 Davis
24. Haman	#1 Bankers Mortgage
25. Pennzoil United Inc.	#1 Grant
26. Heep Oil Corp.	#4 Roquette
27. Halbouty	#1 Hepworth Unit and others
28. Humble Oil and Refining Co.	#1 State Tract 166
29. Humble Oil and Refining Co.	#1 State Tract 222
30. Amerada Petroleum Corp.	#1-G State Tract 198
31. Richardson and Bass	#1 State of Texas Unit Subdivision

Bee County

1. Exxon Co., U.S.A.	#B-27 L. T. Barrow
2. Humble Oil and Refining Co.	#B-9 L. D. Thomson
3. Humble Oil and Refining Co.	#10 Barrow
4. Ames	#1 Taylor
5. Standard Drilling Co.	#1 Canto

Brazoria County

1. Humble Oil and Refining Co.	#2 M. McGarland
2. Southwest Gas Producing Co.	#1 McDonald
3. Lone Star Producing Co.	#1 H. A. Frede
4. Amoco Production Co.	#225 Old Ocean Unit
5. Pan American Petroleum Corp.	#A-1 B.R.L.D. Co.
6. Texas Gas Explor. Corp.	#1 E. S. Smith and others
7. Skelly Oil Co.	#A-1 Poole

Calhoun County

1. Humble Oil and Refining Co.	#1 Schicke
2. Superior Oil Co.	#1 Abraham
3. Superior Oil Co.	#B-1 Traylor
4. Superior Oil Co.	#2 Traylor
5. Tennessee Gas Transmission Co.	#C-1 M. B. Traylor
6. Aluminum Co. of America	#1 Alcoa Fee
7. Arkansas Fuel Oil Corp.	#1 Bauer
8. Republic Natural Gas Co.	#1 M. F. Canion
9. Lone Star Producing Co.	#1-A Foester
10. Humble Oil and Refining Co.	#12 M. T. Vandenberge
11. J. W. Mecom	#12 M. S. Welder
12. Union Carbide Corp.	#1 Clyde Bauer
13. Bering Oil Co.	#1 Wilson
14. Republic Natural Gas Co.	#1 Foester
15. Coloma Oil and Gas Co.	#1 J. G. Stofer
16. Aluminum Co. of America and Southern Prod.	#C-1 Melborn
17. Coastal States Gas Producing and others	#1 Duncan
18. Midwest Oil Corp.	#1 State Tract 21
19. Monsanto Chemical Co. and Ada Oil Co.	#1 State Tract 37
20. Humble Oil and Refining Co.	#12 E. K. Hardie
21. Salt Dome Producing Co.	#1 State Tract 87
22. Texaco, Inc.	#1 State Tract 106
23. Brazos Oil and Gas Co.	#10 Powderhorn Co.
24. Tarpon Oil Co.	#1 DeGolyer and others
25. Texaco, Inc.	#1 State Tract 108
26. Tex-Star	#1 Sam H. Day
27. Mitchell and others (Irish)	#1 Hawes Est.
28. Walter Van Norman	#1 Powderhorn
29. Tennessee Gas Transmission Co.	#1 Stiernberg
30. Arkansas Fuel Oil Corp.	#1 J. J. Welder
31. Edwin L. Cox	#1-A Fisher
32. Brazos Oil and Gas Co.	#1 Tigner
33. Texaco, Inc.	#1 Bowers
34. Glassock and others	#1 State Tract 131
35. Forest Oil Co. and others	#1 State Tract 2
36. George R. Brown	#1 State Tract 78
37. George R. Brown	#1 State Tract 81
38. Western Natural Gas Co.	#1 State Tract 55
39. Gulf Board Oil Corp.	#1 State Tract 114
40. Standard Oil Co. of Texas	#1 State Tract 138
41. Humble Oil and Refining Co.	#1 Shoalwater Bay State Tract 169
42. Aluminum Co. of America	#2 State Tract 172
43. Arkansas Fuel Oil Corp.	#1 J. J. Welder
44. Reynolds Mining	#1 Espiritu Santo Bay State Tract 183
45. Humble Oil and Refining Co.	#1 Espiritu Santo Bay State Tract 201
46. Champlin Petroleum Co.	#1 State Tract 210
47. Champlin Petroleum Co.	#1 State Tract 210
48. Salt Dome Producing Co.	#1 Little
49. Sunray DX Oil Co.	#1 State Tract 122
50. Sunray DX Oil Co.	#1 State Tract 90
51. Getty Oil Co.	#2 American Liberty
52. Getty Oil Co.	#1 American Liberty

Goliad County

1. Lewis Lawler	#1 Berger
2. Atlantic Refining Co.	#1 G. E. Diebel
3. Shell Oil Co.	#1 Friedricks
4. Harding Brothers Oil and Gas Co.	#1 Freidrichs Est.
5. A. B. Alkek	#4 Sol Parks
6. Vaughn Petroleum, Inc.	#1 Summers
7. Braman	#3 Dennis O'Connor
8. Ginther and others	#12 C. G. Wood

Jackson County

1.	Herman Proler	#1 Johnson
2.	J. M. Huber Corp.	#1 Wearden
3.	Gravis and Mitchell	#1 McCulloch
4.	Horace Coon, Jr.	#2 S. G. Sample
5.	Cron and Gracey	#B-1 Heard
6.	H. H. Howell	#1 J. H. Heard
7.	Glassock	#1 O. W. Freeman
8.	Howell, Cox, and Rudman and others	#1 Ben N. Good
9.	J. M. Huber Corp.	#1 J. Grant Unit
10.	Magnolia Petroleum Co.	#1 Henry Peters
11.	Triad Oil and Gas Co.	#1 C. D. Holzheuser
12.	Magnolia Petroleum Co.	#1 Aaron Kolle
13.	Millsap Oil and Gas Co.	#1 A. L. Claybrook
14.	D. M. Wallace	#1-A Miller
15.	Howell and others	#1-F Rose and Sample
16.	Texkan Oil Co. and others	#1 Clark
17.	Edwin L. Cox	#1 Menefee
18.	Mortimer and others	#1 O. M. Oliver
19.	Texas Co.	#1 D. Strickler
20.	Texas Oil and Gas Corp.	#1 Miller and Howle
21.	Mobil Oil Corp.	#25 Gordin Est.
22.	Salt Dome Producing Co.	#1 4-Way Ranch
23.	Pickens	#1 Kramer
24.	Windfohr Oil Co.	#1 E. R. Eversberg
25.	Sun-Texaco	#1 Trumble Unit
26.	Skelly Oil Co.	#A-1 Kunover
27.	Pennzoil United Inc. and Monsanto Chemical Co.	#1 L. Ranch
28.	Forest Oil Corp.	#1 M. Cornish
29.	Texaco, Inc.	#B-1 L. Ranch
30.	Bettis and Shepherd	#1 J. R. Davis
31.	C. C. Gilger	#1 Deunow
32.	Magnolia Petroleum Co.	#A-417 West Ranch
33.	Trinity Drillers Inc.	#1 Mayo-Tucker
34.	Howell and Mayfair Minerals	#1 August Spree
35.	Reese M. Rowling	#1-A Vincik
36.	W. M. Maylor Oil Co.	#1 R. J. Stepan
37.	Union Oil Co. of California	#1 Bennett
38.	Mobil Oil Corp.	#10 W. Rch-State Oil-Gas Unit
39.	Southern Minerals Corp.	#15 Brooking
40.	Superior Oil Co.	#2 L. Weaver
41.	Sun Oil Co. DX Div.	#1 W. F. Weed
42.	Monsanto Chemical Co.	#1 Texas-Gulf Sulphur Fee

Matagorda County

1.	Mid-Century Oil and Gas Co.	#1-A Florence W. Howard
2.	Frazier and Ferguson	#1 Pierce Est.
3.	Lenoir M. Josey Inc.	#2 Pierce Est.
4.	Skelly Oil Co.	#14-B Cobb
5.	Cerro de Pasco Corp.	#1 Lewis
6.	BBM Drilling Co.	#1 Miekow
7.	Lario Oil and Gas and Felmont Oil Corp.	#1 Corbett
8.	Superior Oil Co.	#1 Johnson
9.	Ancon Oil and Gas Inc. and others	#1 M. P. Tew Unit
10.	Humble Oil and Refining Co.	#1 First City Nat'l. Bank of Houston Trustee
11.	Plymouth Oil Co.	#1 Lawson
12.	British-American Oil Producing Co.	#1 Guess
13.	Falitz and Mitchell	#1 Howard
14.	Nelson Bunker Hunt	#1 Burkhart
15.	Mobil Oil Corp.	#15 Cornelius
16.	Skelly Oil Co.	#1 J. S. Long
17.	Pan American Petroleum Corp.	#1 Sherrill Gas Unit
18.	Humble Oil and Refining Co.	#1 Pauline Huebner
19.	Hamman Oil and Refining	#2 Richter
20.	Hamman Oil and Refining and others	#1 Huebner
21.	Monsanto Chemical Co.	#1 Lee
22.	Gulf Oil Corp.	#1 Gilmore and others Unit
23.	Cosden Petroleum Co.	#1 W. D. Cornelius Unit 2
24.	Monsanto Chemical Co.	#1 Cornelius Cattle Co.
25.	Bradeo Oil and Gas	#1 Elizabeth Burkhart and others
26.	Continental Oil Co.	#1 Fondren and others
27.	Josey and Coffee	#1 G. S. Reifslager
28.	Sun Oil Co.	#1 Clara Junek
29.	Occidental Petroleum Corp.	#1 Dawdy and others
30.	Manco Corp.	#1 Kountze
31.	E. Cockrell, Jr.	#1 Neuszer and others
32.	Mobil Oil Corp.	#1 Michalik
33.	Travis Oil Co. and Tidewater Oil Co.	#1 B. L. Backen
34.	Ada Oil Co.	#1 Fletcher
35.	Fullerton Oil Co.	#1 Heffelfinger
36.	Monsanto Chemical Co.	#1 Buckeye
37.	George R. Brown	#1 Jennie Grant
38.	British-American Oil Producing Co.	#1 Buckner's Orphan House
39.	Phillips Petroleum Co.	#1 Pierce
40.	Magnolia Petroleum Co.	#1 Rugeley
41.	Pan American Petroleum Corp.	#1 T. J. Petrucha
42.	Tennessee Gas Transmission Co.	#1 Willie Doss
43.	Magnolia Petroleum Co.	#1 Cornelius
44.	Gulf Oil Corp.	#2 H. B. Hawkins
45.	Skelly Oil Co.	#1 Hawkins
46.	Falcon Seaboard Drilling Co.	#A-1 Baer Ranch
47.	Magnolia Petroleum Co. and others	#1 Letulle
48.	Falcon Seaboard Drilling Co.	#1 Letulle
49.	Socony-Mobil	#3 Hawkins
50.	Gulf Oil Corp.	#B-1 Mary Vineyard and others
51.	Buttes Gas and Oil Co.	#1 Vinyard
52.	Gulf Oil Corp.	#1-A Sanborn
53.	Gulf Oil Corp.	#1 O. E. Phillips
54.	Phillips Petroleum Co.	#1-A State "N"
55.	Gulf Oil Corp.	#1 Hammil and others
56.	Union Producing Co.	#1 State Tract 77
57.	Ethyl Corp. and others	#1 Baer Ranch
58.	North Central Oil Corp.	#1 State Tract 105
59.	Union Producing Co.	#1 State Tract 100
60.	Falcon Seaboard Drilling Co.	#2-A Baer Ranch
61.	American Petrofina Explor. Corp.	#1 D. H. Braman
62.	Wheelock and others	#1 McNabb
63.	Occidental Petroleum Corp.	#1 State Tract 128
64.	Hawkins and others	#1 P. Huebner
65.	Superior Oil Corp.	#1 Robbins Est.
66.	Slick	#1 Johnson Gas Unit
67.	Cockburn	#1 Vanwormer
68.	Brazos Oil and Gas Co.	#2 Stewart Savage
69.	Brazos Oil and Gas Co.	#1 H. M. Holsworth
70.	Halbouty	#1 Stanley Kubela
71.	Tidewater Oil Co.	#1 Nelson
72.	Sinclair Oil and Gas	#1 Miller Gas Unit
73.	Pan American Petroleum Corp.	#1 Silver Lake Ranch
74.	Skelly Oil Co. and Sunray DX	#1-D Gulf (State Tract 291)
75.	Humble Oil and Refining Co.	#1 State Tract 316
76.	Midwest (Mobil)	#1 Letulle Ranch
77.	T. T. Co.	#1 Huebner
78.	Sinclair Oil and Gas	#1 State Tract 257
79.	T. T. Co.	#1 Phillips
80.	North American Royalty	#1 State Tract 179
81.	Shell Oil Co.	#1 State Tract 143

Nueces County

1.	Superior Oil Corp.	#1 O. E. Davis
2.	Southern Minerals Corp.	#1-A Lawrence
3.	Coastal States Gas Producing Co.	#1 Butt
4.	Bell and Dansfield	#1 Baldwin Farms
5.	Phillips Petroleum Co. and Texaco, Inc.	#1 Water State Tract 750
6.	Cities Service Oil Co.	#1 State Tract 59
7.	Republic Natural Gas Co.	#3 State Tract 786
8.	Cities Service Oil Co.	#1 State Tract 26
9.	Cities Service Oil Co.	#2 State Tract 10
10.	Cities Service Oil Co.	#B-1 State Tract 71
11.	Glassock and others	#1 State Tract 56
12.	Cities Service Oil Co. and others	#1 State Tract 52
13.	Atlantic Richfield Co.	#1 State Tract 36
14.	Atlantic Richfield Co.	#1 State Tract 33
15.	Austral Oil Explor. Co.	#1 State Tract 20
16.	Atlantic Refining Co. and others	#1 State Tract 470
17.	King Resources	#1 State Tract 336
18.	Shell Oil Co.	#1 State Tract 346 Redfish Bay
19.	Mobil Oil Corp.	#1 State Tract 310
20.	Humble Oil and Refining Co.	#1 State Tract 312
21.	Pure	#1 Little
22.	Tenneco Oil Co.	#1 State Tract 458
23.	Getty Oil Co.	#1 State Tract 41
24.	Cherryville Corp.	#1 State Tract 81
25.	Coastal States Gas Producing Co.	#1 B. Dunn and others
26.	Marion Corp.	#1 Peterson
27.	Atlantic Refining Co.	#1 Pearse
28.	M. Bennett Producing Co.	#1 Poenisch
29.	J. L. Hamon	#1 Peterson Properties Inc.
30.	Pan American Petroleum Corp.	#1 U.S.A.
31.	Cherryville Corp.	#1 Cech
32.	Getty Oil Co.	#1 Bevly
33.	Cherryville Corp.	#1 Geistman Unit

Refugio County

1.	Humble Oil and Refining Co.	#1 Shay
2.	Clymore Petroleum Corp.	#1 Sullivan
3.	Mana Oil Corp.	#1 M. S. Huff
4.	Tennessee Gas Transmission Co.	#F-25 J. A. Hynes
5.	Atlantic Refining Co.	#2 Tom O'Connor
6.	Union Oil Co. of California	#A-1 Thelma Heard
7.	Southern Petroleum Explor. Inc.	#1 Hynes
8.	Quintana Petroleum Corp.	#D-6 M. Williams "A"
9.	Maran Oil Co.	#C-1 Anderson
10.	P. H. Welder	#1 J. L. Zarsky
11.	Morgan Minerals Corp.	#1 Tolbirt
12.	Texas Oil and Gas Corp.	#1 J. G. Turner
13.	Magnolia Petroleum Co.	#1 Calloway
14.	Union Producing Co.	#C-1 Tatton Ranch
15.	Union Producing Co.	#8 Tatton
16.	Pan American Petroleum Corp.	#1 Tatton Ranch
17.	Quintana Petroleum Corp.	#A-114 O'Connor
18.	Burdette Graham	#1 W. J. Fox
19.	Seaboard Oil Co. and others	#A-4 Hynes
20.	Dallas Husky	#1 W. Heard
21.	Atlantic Richfield Co.	#68 P. H. Rooke
22.	Continental Oil Co.	#1 Heard and others
23.	Harkins and Co.	#1-A R. W. Welder
24.	Wynne Drilling Co.	#1 Roach
25.	Texaco, Inc.	#2 Roche
26.	Marathon Oil Co.	#E-20 Welder
27.	4-B Trust	#1 Rooke
28.	Hunt	#1 Woods
29.	Taggart and Cochran	#1 Fricke
30.	Cox	#1 Dammann
31.	Harkins and Co.	#1 J. Veselka
32.	Harkins and Co.	#2 Smith-Crow
33.	Sunray-Mid-Continent	#1 Hartman
34.	Glassock	#8 State Tract 29
35.	Sun Oil Co.	#1 F. U. Falfrey
36.	Zoch and Wynne	#1 Heinlein

San Patricio County

1.	Hewitt and Doughtery	#1 Smith
2.	Amerada Petroleum Corp.	#1 Stalcup
3.	Tom Graham	#1 Morgan
4.	Midland Producing Corp.	#1 Hunt
5.	R. L. and J. L. Rush	#1 San Antonio Loan and Trust Co.
6.	Plymouth Oil Co.	#H-1 R. H. Welder
7.	Superior Oil Co.	#27 M. S. Welder
8.	Atlantic Richfield Co.	#1 L. E. Fite
9.	Austral Oil Explor. Co.	#1 Green Est.
10.	Engeo Oil and Gas Co.	#B-3 Mayo
11.	Plymouth Oil Co.	#E-8 Welder
12.	McCulloch-IDS	#1 Boehm and others
13.	Mobil Oil Corp.	#1 Bren
14.	Bruce Fox	#1 Wendland
15.	Royal Oil and Gas Corp.	#1 Tutt
16.	Sun Oil Co.	#1 Gabriel
17.	Pan American Petroleum Corp.	#1 Bankers Mortgage
18.	Tenneco Oil Co.	#1 McCampbell
19.	Union Oil Co. of California and others	#1 Coward Unit
20.	Midwest Oil Corp.	#3 McCampbell Est.
21.	Jake L. Hamon	#2 Harvey
22.	Jake L. Hamon	#1 R. C. Dillon
23.	Union Texas Natural Gas Corp.	#1 Jones
24.	American Petrofina Explor. Corp.	#1 Green Est.
25.	Texas Co.	#1 Green Est.
26.	Conroe Drilling Co. and others	#1 Hunt
27.	Lawbar Petroleum, Inc.	#1 Hunt-Dugat
28.	Hada and others	#1 Gierke
29.	Phillips Petroleum Co.	#1 Flynn
30.	Getty Oil Co.	#1 Wilkerson
31.	Spartan Drilling. Co.	#1 Granberry
32.	Mrs. James R. Dougherty	#1 Webb
33.	Southern Minerals Corp.	#1 Griffin
34.	Seaboard Oil Co.	#3 Smith
35.	Skelly Oil Co.	#1 Smith

Victoria County

1.	Rodney Delange and others	#3 C. K. McCan
2.	R. B. Roos	#1 Ben McCormick
3.	Foster and Gregg	#1 Benbow
4.	Robert Rosenberg Trustee	#1 Osbta
5.	Logue and Patterson, Inc.	#1 Filgas
6.	Logue and Patterson, Inc.	#1 L. L. Beyes
7.	Jefferson Lake Sulphur Co.	#1 Keeran Ranch
8.	Howell and Cox	#2 Jack C. Goodson
9.	J. L. Hada	#1 Dolly Angerstein
10.	Bobby M. Bruns	#1 Jones
11.	Fort Bend Oil Co.	#1 Schovajsa
12.	H. L. Ike Poole	#1 Small and others
13.	Cattle-Land Oil Co.	#1 Tipton
14.	Sohio Petroleum Co.	#1 A. J. Albrecht
15.	Danciger Oil and Refining Co.	#1 J. Baass
16.	Fly and Cliburn and others	#1 Morris
17.	Dougherty	#1 Marbach
18.	Golden Trend Oil and Gas Corp.	#1 Warburton
19.	Harkins and Co.	#1 Henderson-Pickering
20.	George C. Ayres	#1 Keeran
21.	Union Producing Co. and others	#A-34 McFaddin

22. Champlin Petroleum Co.	#A-10 J. A. McFaddin
23. Sunray Mid-Continent Oil Co.	#46 McFaddin
24. Harkins and Co. and Cox	#1 Simmons

Wharton County

1. Robert Merritt	#1 Otto
2. Tidewater Associated Oil Co.	#1 Vacek
3. Western Oil Corp.	#2 Sklar Alliance Trust
4. Sunray Mid-Continent Oil Co.	#1 Duncan
5. Scurlock Oil Co.	#1 Waddell
6. ACCO-Colorado Amurex	#1 Elliot
7. George R. Brown	#1 Peter Gerston, Jr.
8. Claude B. Hamill	#2 Duncan
9. Mackey Oil Co.	#2 Matusek
10. Davidor and Davidor Inc.	#1 Moore
11. Cerro de Pasco Corp.	#1 Gary Est.
12. Haggarty	#1 Lily B. Outler
13. Texkan Oil Co.	#1 Mary D. Rowe
14. Magnolia Petroleum Co.	#1 Borden
15. Curtis Hankamer	#1 Hobbs and LeFort
16. J. S. Michaels	#2 F. B. and Donald Duncan
17. Mid American Oil Co.	#1 Miller
18. Guy F. Stovall	#1 Lichnovsky
19. McDonnald Oil Co.	#1 Dortek
20. W. R. Davis Inc.	#1 Hortman
21. Greenbrier Oil Co.	#1 Wendel
22. Hamill and Sunray DX Oil Co.	# 1 Henderson
23. ACCO Oil and Gas Corp.	#1 Schmidt
24. ACCO Oil and Gas Corp.	#1 Harfst
25. ACCO Oil and Gas Corp. and Colorado Oil and Gas	#2 Meek
26. Sun Oil Co.	#1 Hawes
27. Lloyd Smith Inc.	#1 Rufus Johnstone and others
28. L. M. Josey and others	#12 Bergwall-Montgomery
29. C. C. Winn	#1 Selma Kainer
30. F. S. Pratt	#1 Fleer
31. R. B. Mitchell	#1 H. C. Cockburn
32. Texas Republic Petroleum Co., Inc.	#1 G. R. Hawes
33. MacDrilling Co. and John Mayo	#1 Gary Est.
34. Brazos Oil and Gas Co. and Halbouty	#2 Blue Creek Ranch
35. W. M. Kick, Jr.	#1 Leisner
36. Moore and Ahern	#1 Hans Johnson
37. Helmerick and Payne	#1 Myatt
38. Marlin Explor. Co.	#1 Braden
39. Ben D. Marks	#1 Kountze and Stewart
40. ACCO Oil and Gas Corp.	#1 J. K. Allen

Offshore

Brazos area

1. Superior Oil Co.	#1 State Tract 482-S
2. Texaco, Inc.	#1 State Tract 403-L (N.E.)
3. Texaco, Inc.	#1 State Tract 404-L (N.E.)
4. Shell Oil Co.	#1 State Tract 405-L (N.E.)
5. Shell Oil Co.	#1 State Tract 404-L (S.W.)
6. Shell Oil Co.	#1 State Tract 488-S
7. Kilroy Co. of Texas	#2 State Tract 509-S
8. Shell Oil Co.	#1 State Tract 408-L (N.W.)
9. Shell Oil Co.	#1 State Tract 406-L (N.E.)
10. Shell Oil Co.	#1 State Tract 440-L
11. Humble Oil and Refining Co.	#1 State Tract 439-L
12. Shell Oil Co.	#1 State Tract 534-S
13. Pan American Petroleum Corp.	#1 State Tract 443-L (S.W.)
14. Shell Oil Co.	#2 State Tract 446-L (S.E.)
15. Mobil Oil Corp.	#1 State Tract 480-L

Matagorda Island area

16. Socony Mobil	#1 State Tract 481-L
17. Superior Oil Co.	#1 State Tract 582-S
18. Tidelands Oil Corp. and Superior Oil Co.	#1 State Tract 483
19. Shell Oil Co.	#1 State Tract 485 (S.E.)
20. Western Natural Gas Co.	#2 State Tract 608-S
21. Shell Oil Co. and Humble Oil and Refining Co.	#1 State Tract 520-L (N.W.)
22. Texaco, Inc.	#1 State Tract 525-L (N.W.)
23. Atlantic Richfield Co.	#1 State Tract 526-L
24. Atlantic Richfield Co.	#1 State Tract 525-L
25. Mobil Oil Corp.	#1 State Tract 565-L
26. Coastal States Gas Producing Co.	#1 State Tract 592-L
27. Texaco, Inc.	#1 State Tract 562-L
28. Humble Oil and Refining Co.	#1 State Tract 599-L (N.E.)
29. Mobil Oil Corp.	#1 State Tract 600-L
30. Humble Oil and Refining Co.	#1 State Tract 598-L
31. Mobil Oil Corp.	#1 State Tract 625-L
32. Humble Oil and Refining Co.	#1 State Tract 657-L
33. Highland Resources Inc.	#2 State Tract 691-L (S.W.)
34. Shell Oil Co.	#1 State Tract 691-L (S.W.)
35. Shell Oil Co.	#1 State Tract 691-L (N.W.)
36. Humble Oil and Refining Co.	#1 State Tract 794-S
37. Humble Oil and Refining Co.	#1 State Tract 692-L
38. Shell Oil Co.	#1 State Tract 692-L (S.E.)
39. Coastal States Gas Producing Co.	#1 State Tract 831-S
40. Standard Oil of Texas	#1 State Tract 833-S
41. Belco Petroleum Corp.	#1 State Tract 721-L (S.E.)

Mustang Island area

42. Shell Oil Co.	#1 State Tract 884-S
43. Gulf Oil Co.	#1 State Tract 889-S
44. Gulf Oil Co. and others	#B-1 State Tract 772-L
45. Union Oil Co. of California	#1 State Tract 775-L
46. Gulf Oil Corp.	#1 State Tract 774-L
47. Zapata, C and K	#1 State Tract 773-L
48. Shell Oil Co.	#1 State Tract 899-S
49. Cities Service Oil Co.	#1 State Tract 773-L